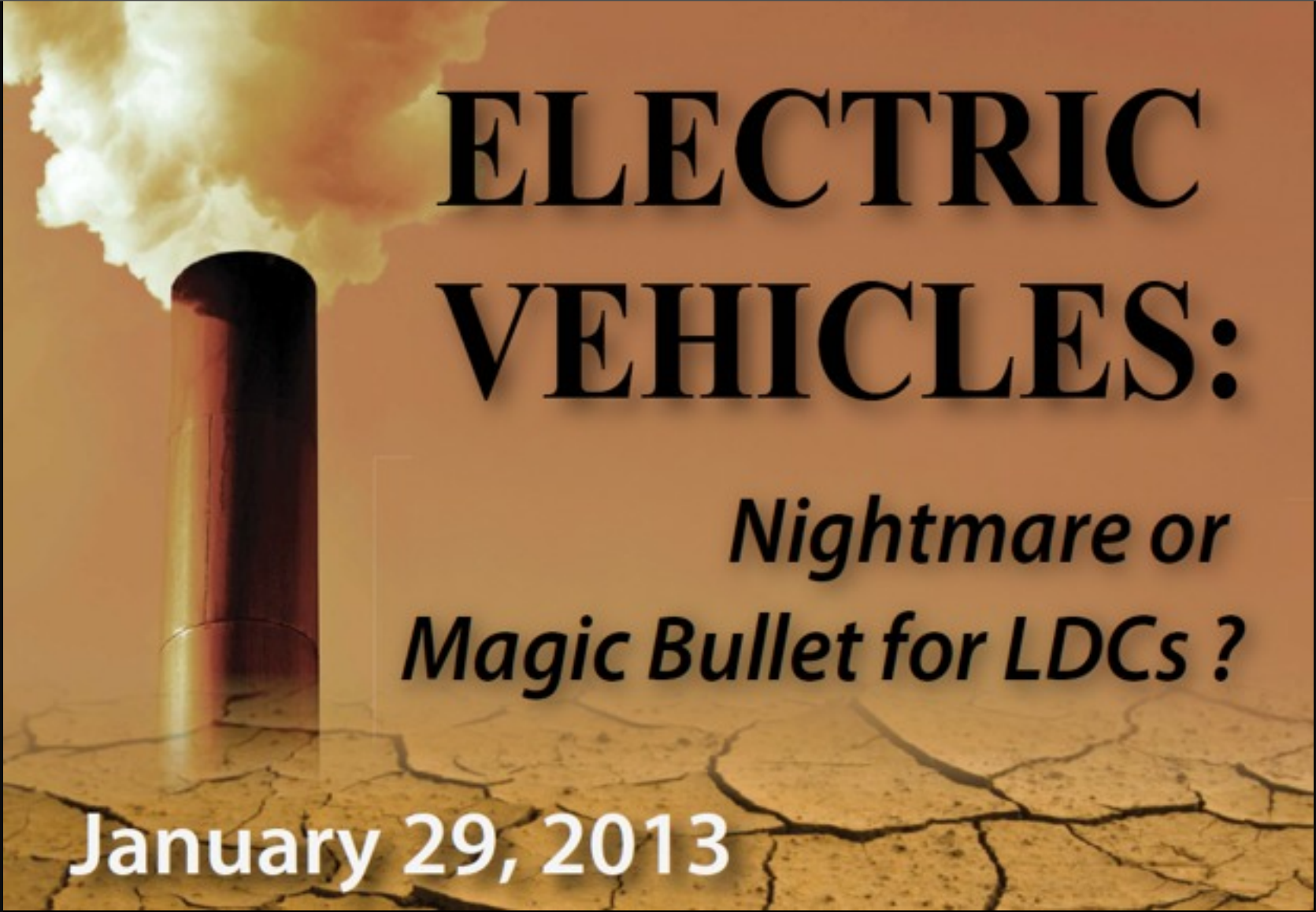




# ELECTRIC VEHICLES:

*Nightmare or  
Magic Bullet for LDCs ?*

January 29, 2013



**Carleton**  
UNIVERSITY



Carleton Research Unit on Innovation, Science & Environment



Carleton Sustainable Energy Research Centre

# Disclaimer & Notice of Intent

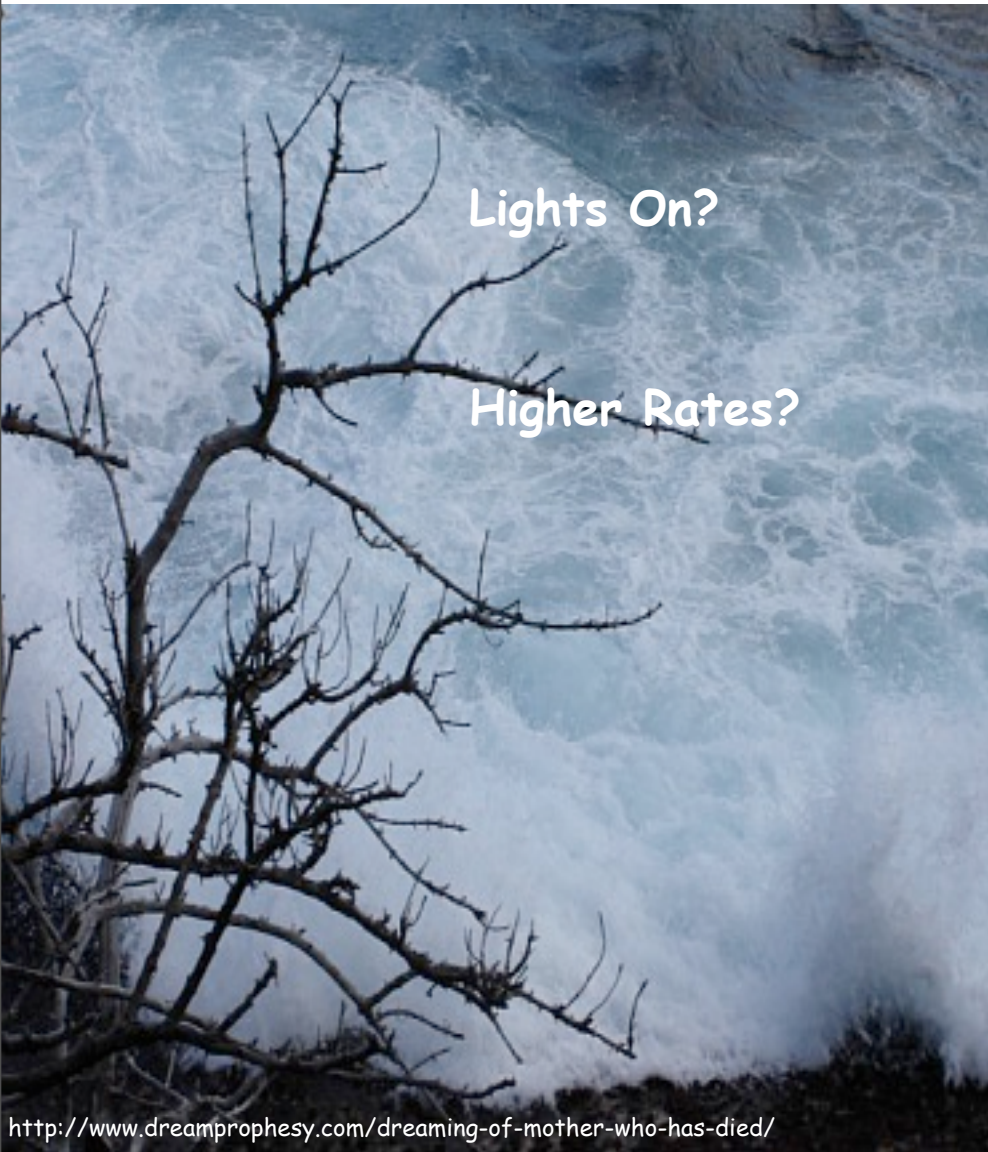
The information and opinion presented may not have been endorsed by or reflect the opinion of Hydro Ottawa (or its employees), those of IEEE members, those of Electric Mobility Canada (or its employees or members), or those of anyone else except the presenter – Raed Abdullah, P.Eng., SMIEEE.

The information and opinion presented will hopefully challenge your views to make what might be a nightmare into a realizable dream.

If you disagree with or are dismayed with what is presented, take it up with the presenter – Raed Abdullah, P.Eng., SMIEEE.

# EVs

## Grid Nightmare or Magic Bullet for LDCs?



Lights On?

Higher Rates?

<http://www.dreamprophesy.com/dreaming-of-mother-who-has-died/>



**LIGHTS ON!**

**HIGHER  
UTILIZATION  
FACTOR**

**NEW BUSINESS /  
HIGHER PROFIT**

**GREAT CUSTOMER  
ENGAGEMENT**

**SUSTAINABILITY  
/ GREAT  
CORPORATE  
CITIZENSHIP**

<http://www.oplife.org/our-dreams-and-our-goals/>



# Thought Map



Grid Management Planning  
Grid Layers  
Parties to the Grid  
Waves of Change...

<http://www.fresheyesediting.com/setting-the-stage-guidelines-for-writing-an-introduction-to-a-scientific-article/>



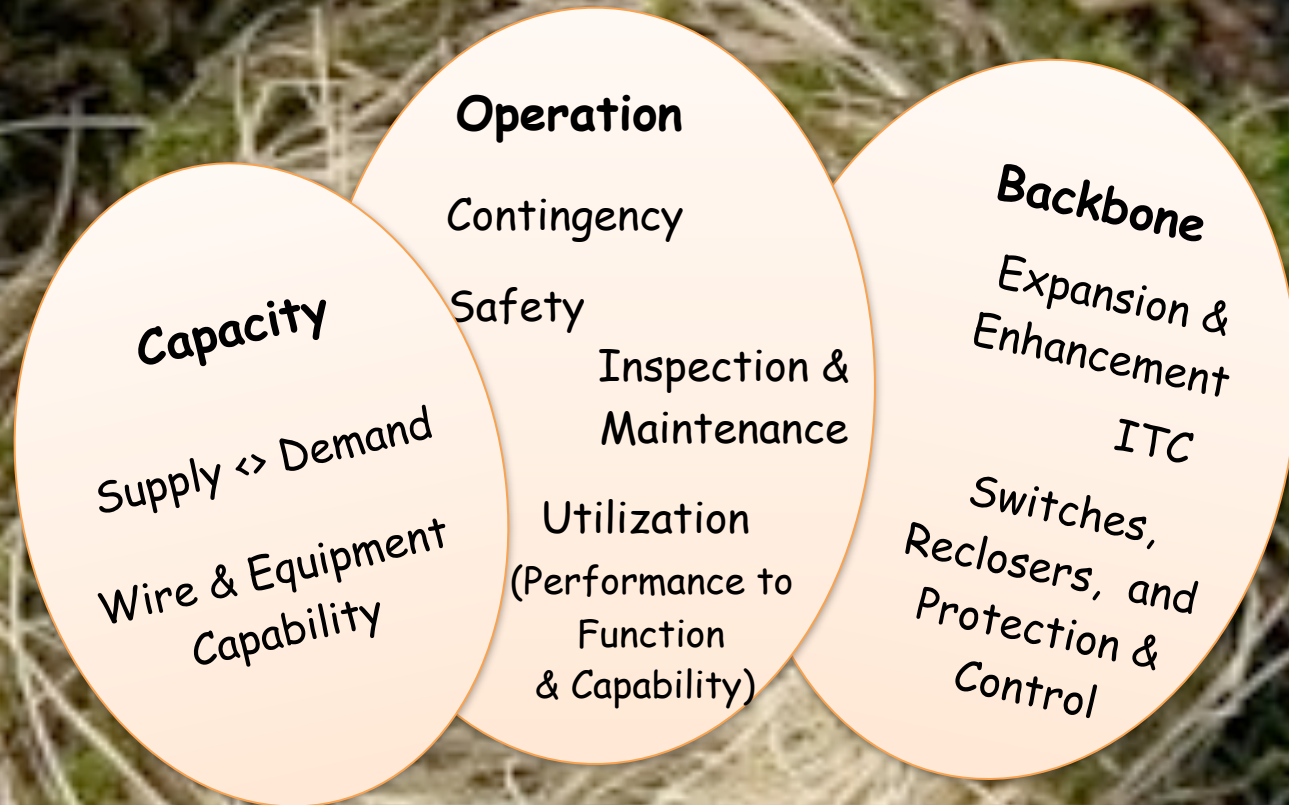
**Staying in Touch & Resources**

Q&A

**Change the Nightmare to a Dream**



# Grid Management Planning



Customer Service

Cost /  
Benefit

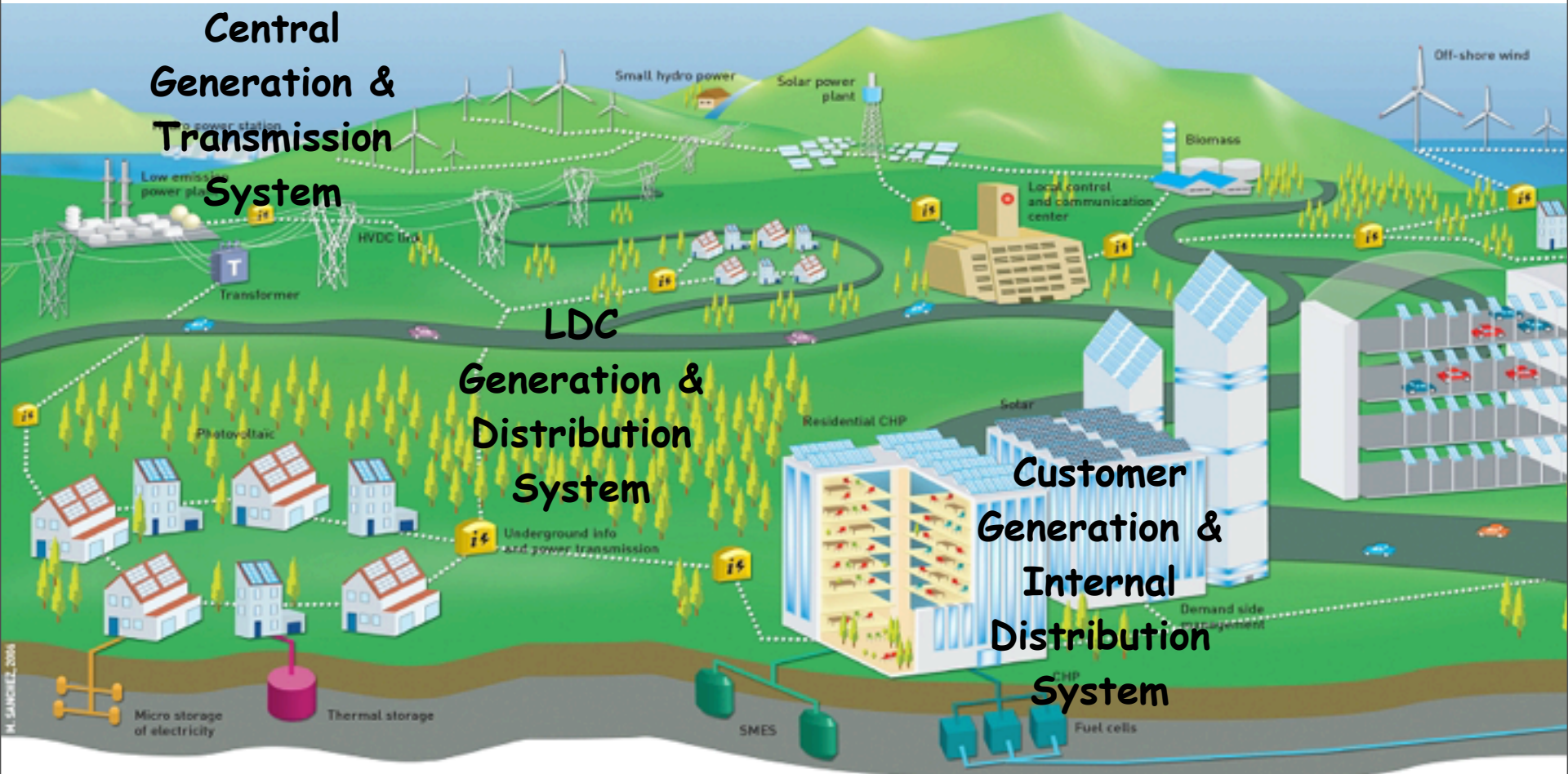
Reliability  
(Availability & Stability)

Efficiency

Sustainability

Customer  
Control

# Grid Layers



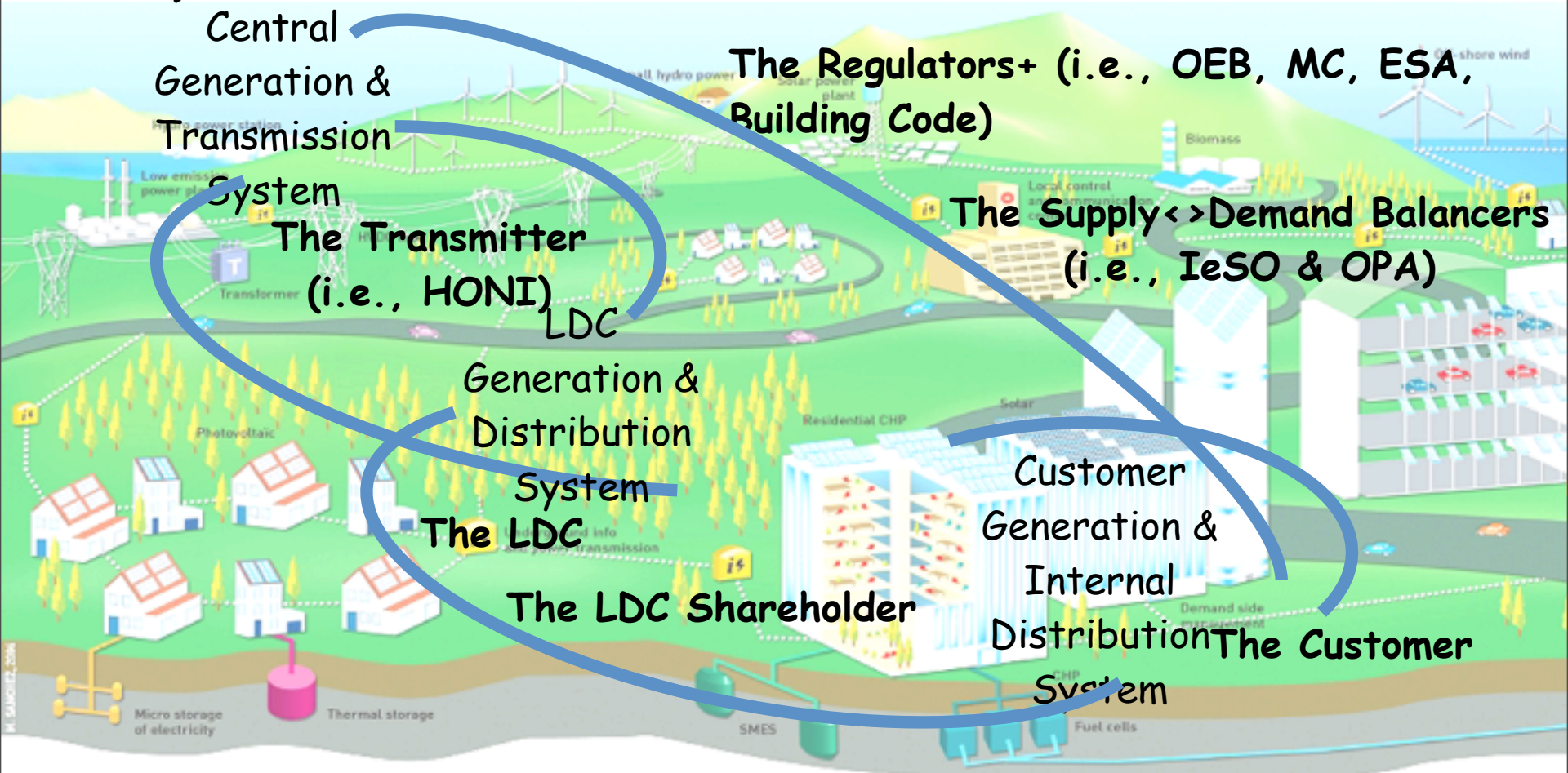
The European Smart Grids Technology Platform – Future Network Vision



The Large  
Generators (i.e.,  
OPG & APPRO  
members)

# Parties to the Grid

## The Politico



The European Smart Grids Technology Platform – Future Network Vision



# Grid Layers



M. SANCHEZ, 2008



X ?????

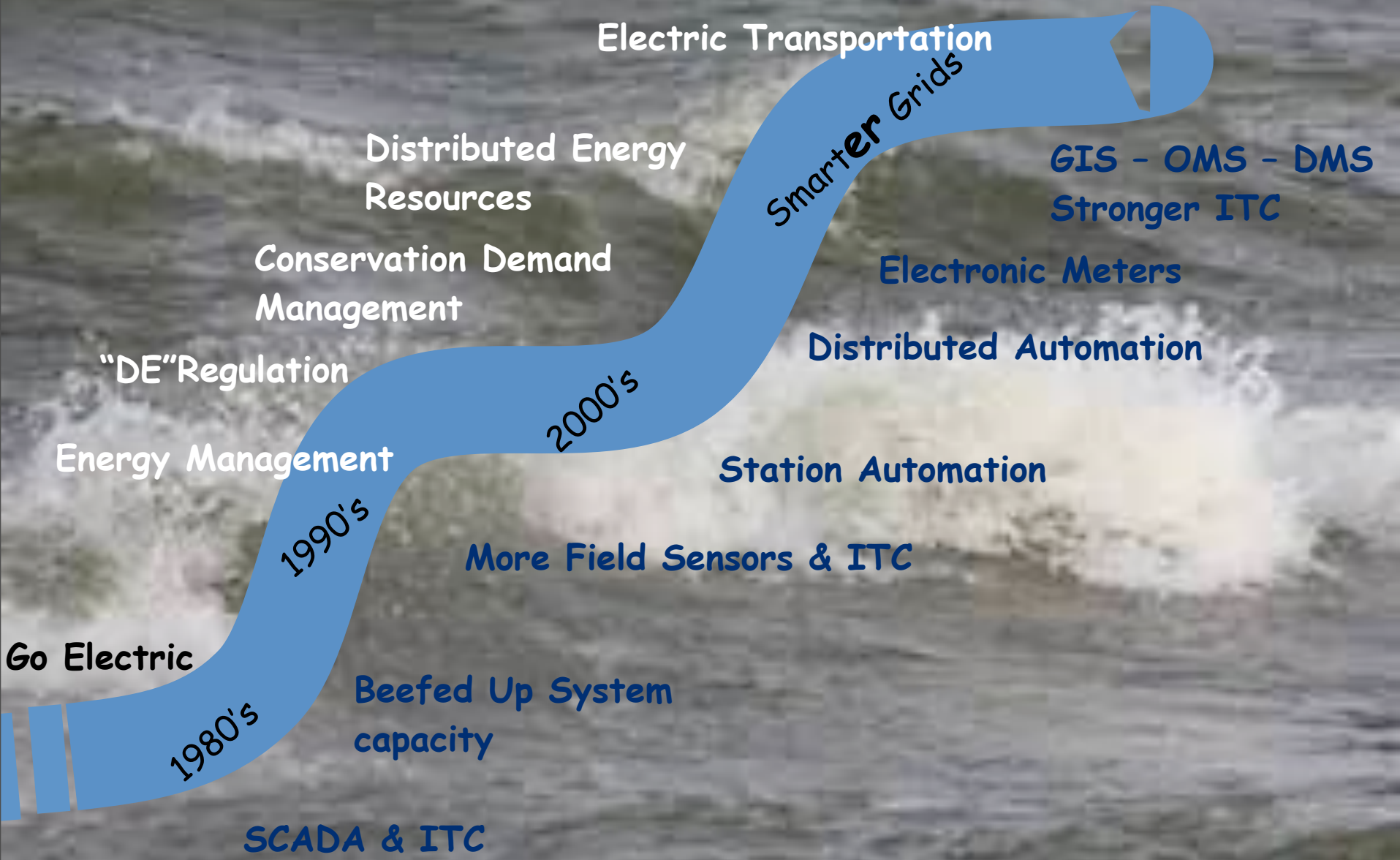
© beboy \* [www.ClipartOf.com/30316](http://www.ClipartOf.com/30316)



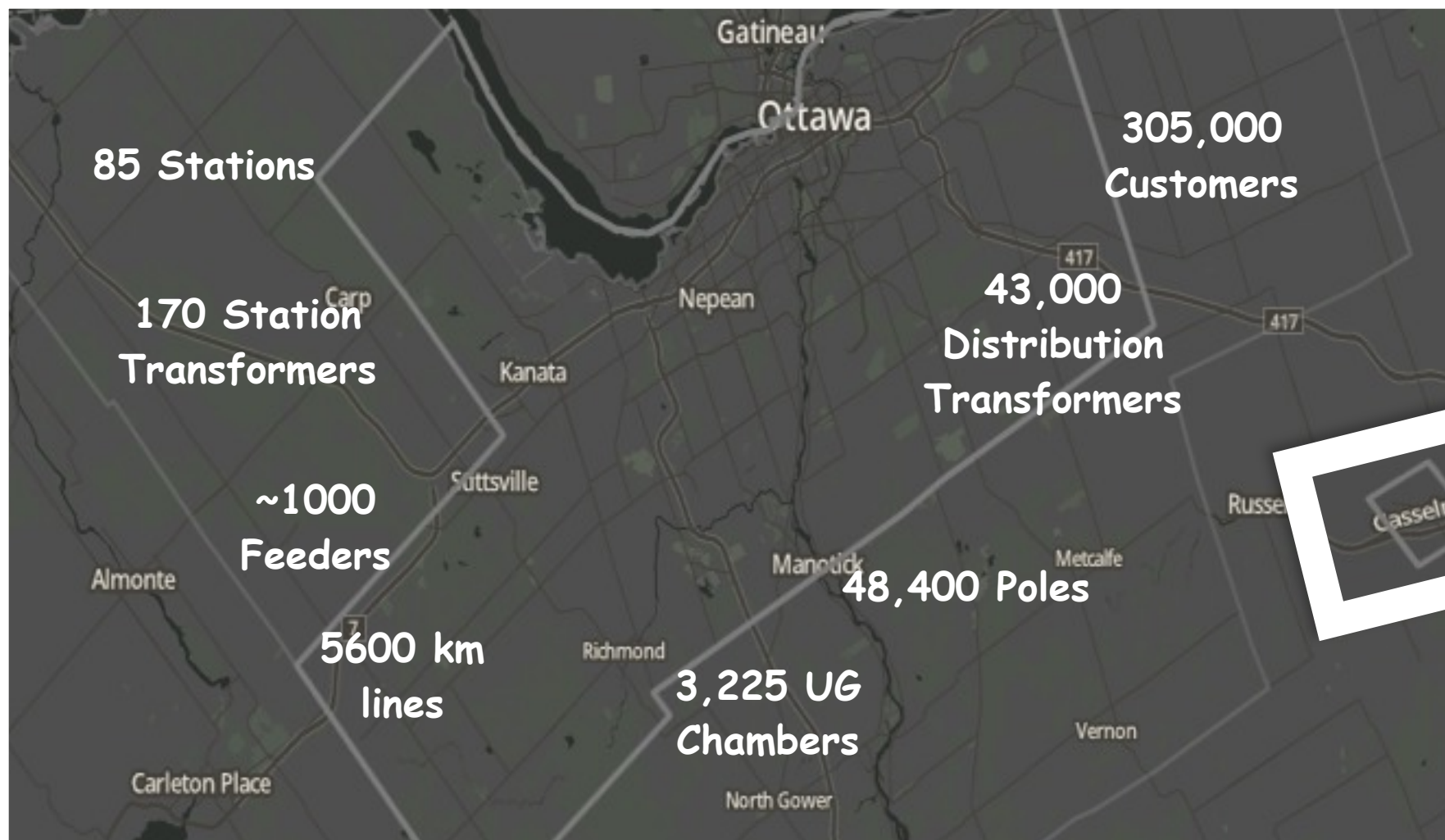
The European Smart Grids Technology Platform – Future Network Vision



# Waves of Change >>> Smarter Grids

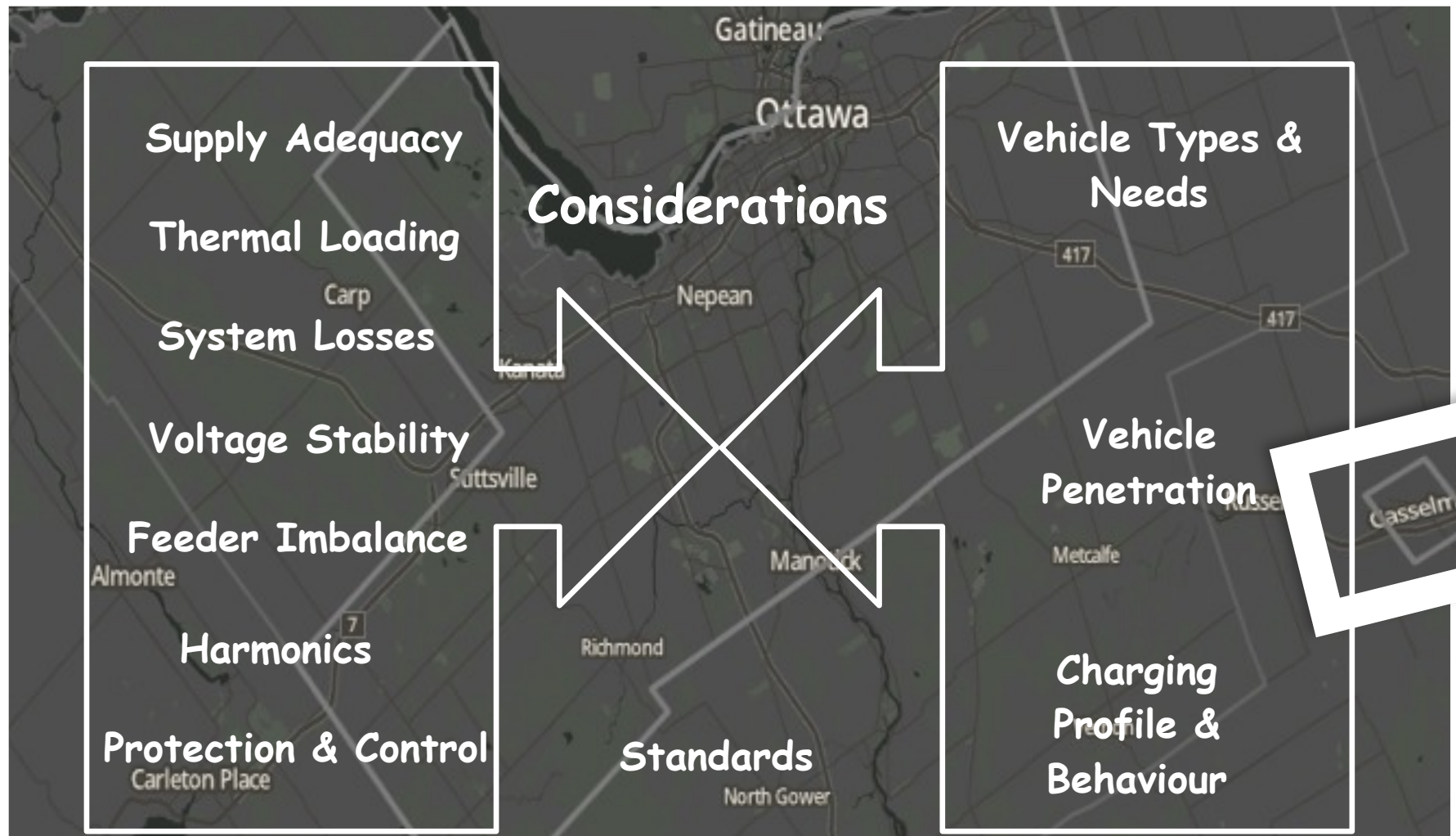


# Where to Start?





# Where to Start?



# Types & Needs

## G2V



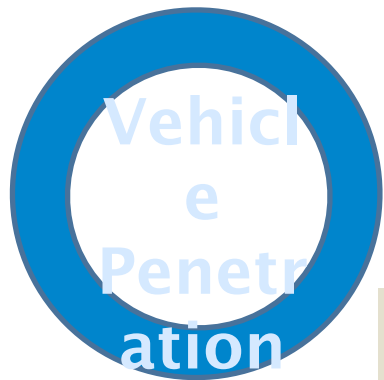
Cost BEV/EREV: \$35k to \$120k

Battery Pack: 16, 24, 50, 85kWh

Cost PHEV: \$20k to \$120k

Battery Pack: 4.4, 7.4, 16, 20kWh





# G2V

"...plug-ins represented roughly 0.1 percent of Canadian new car sales, or about 1,800 out of 1.7 million vehicles.

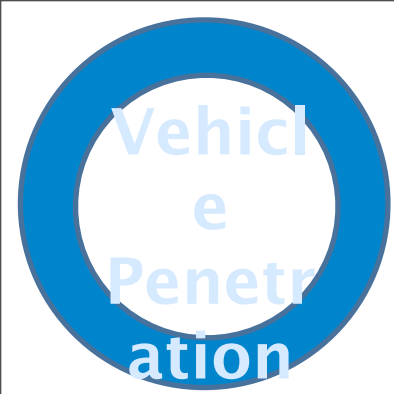
That's lower than plug-ins' market share in the US (0.3 percent), despite Canadians paying more for gasoline and less for electricity than U.S. buyers."

"...the Volt ended 2012 with its 1,500th cumulative Canadian sale.

In 2012, the Nissan Leaf (240) and Mitsubishi i-MiEV (196) trailed far behind in second and third place. The Toyota Prius Plug-In Hybrid, arriving in September, took fourth place (63) but outsold both the Leaf and i-MiEV in each of its four months on the market."

Matthew Klippenstein, Jan 21, 2013 ...

[http://www.greencarreports.com/news/1081799\\_plug-in-electric-car-sales-in-canada-a-2012-review](http://www.greencarreports.com/news/1081799_plug-in-electric-car-sales-in-canada-a-2012-review)



"[Ontario] to have one out of every 20 vehicles driven in Ontario to be electrically powered by 2020;"

Premier Dalton McGuinty, 2009/07/15

Shell expects electricity-powered vehicles to account for as much as 40% of the worldwide car market by 2050.

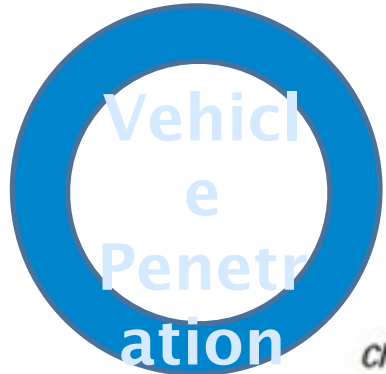
PETER VOSER, CHIEF EXECUTIVE OFFICER, ROYAL DUTCH/SHELL

"Plug-in electric vehicles (PEVs) are forecast to reach 400,073 annual sales in the United States and 107,146 in Canada by 2020"

In Canada, the provinces of Ontario, Quebec, and British Columbia, which account for 75% of the Canadian population, will represent 97% of Canadian PEV sales by 2020. Toronto and Montreal will lead Canadian PEV sales.

Pike Research "Electric Vehicle Geographic Forecasts"





G2V



In Ontario  
2020 ~ 50k  
2017 ~ 30k  
2014 ~ 10k  
2012 ~ < 2.5k

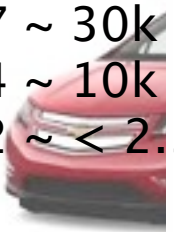
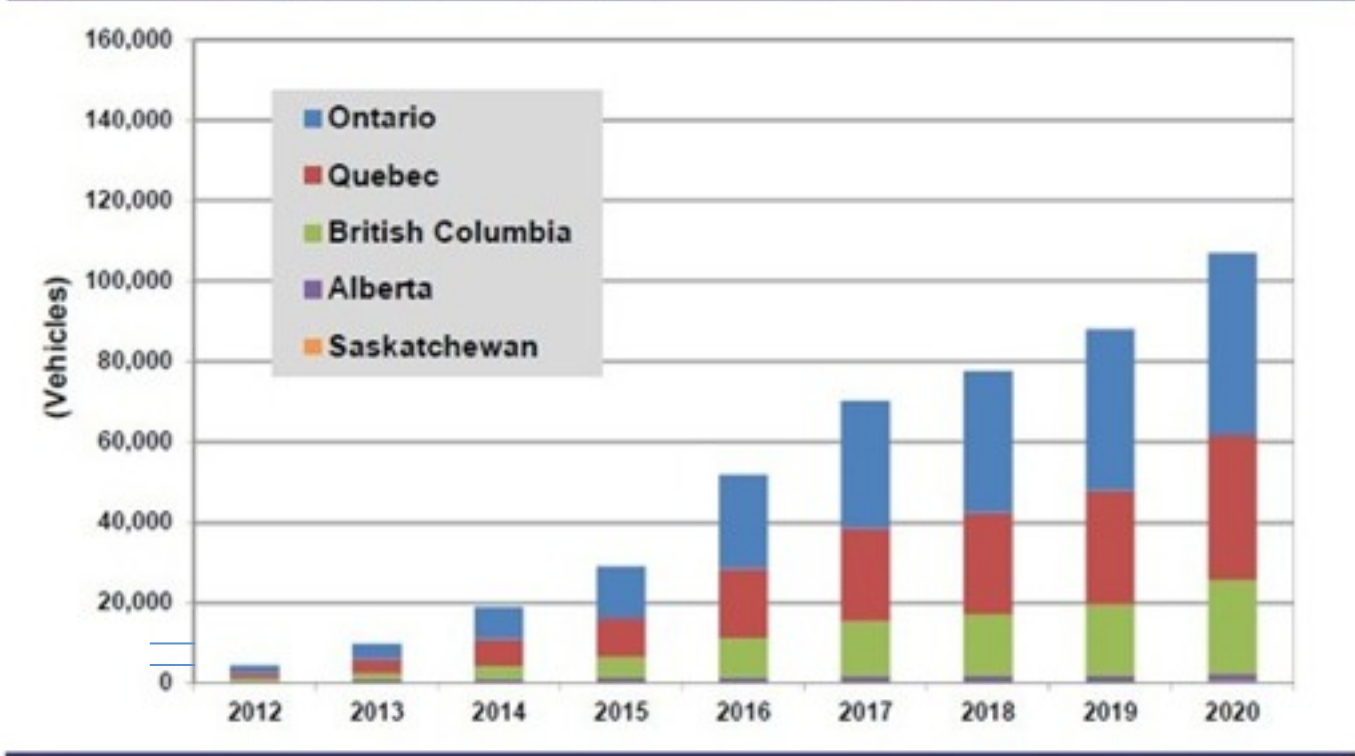


Chart 1.2 Annual Light Duty PEV Sales, Top Five Provinces, Canada: 2012-2020



(Source: Pike Research)



Vehicle  
Penetration

G2V



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Sunday, 10 March, 13

Vehicle  
Penetration

G2V



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Sunday, 10 March, 13



When?

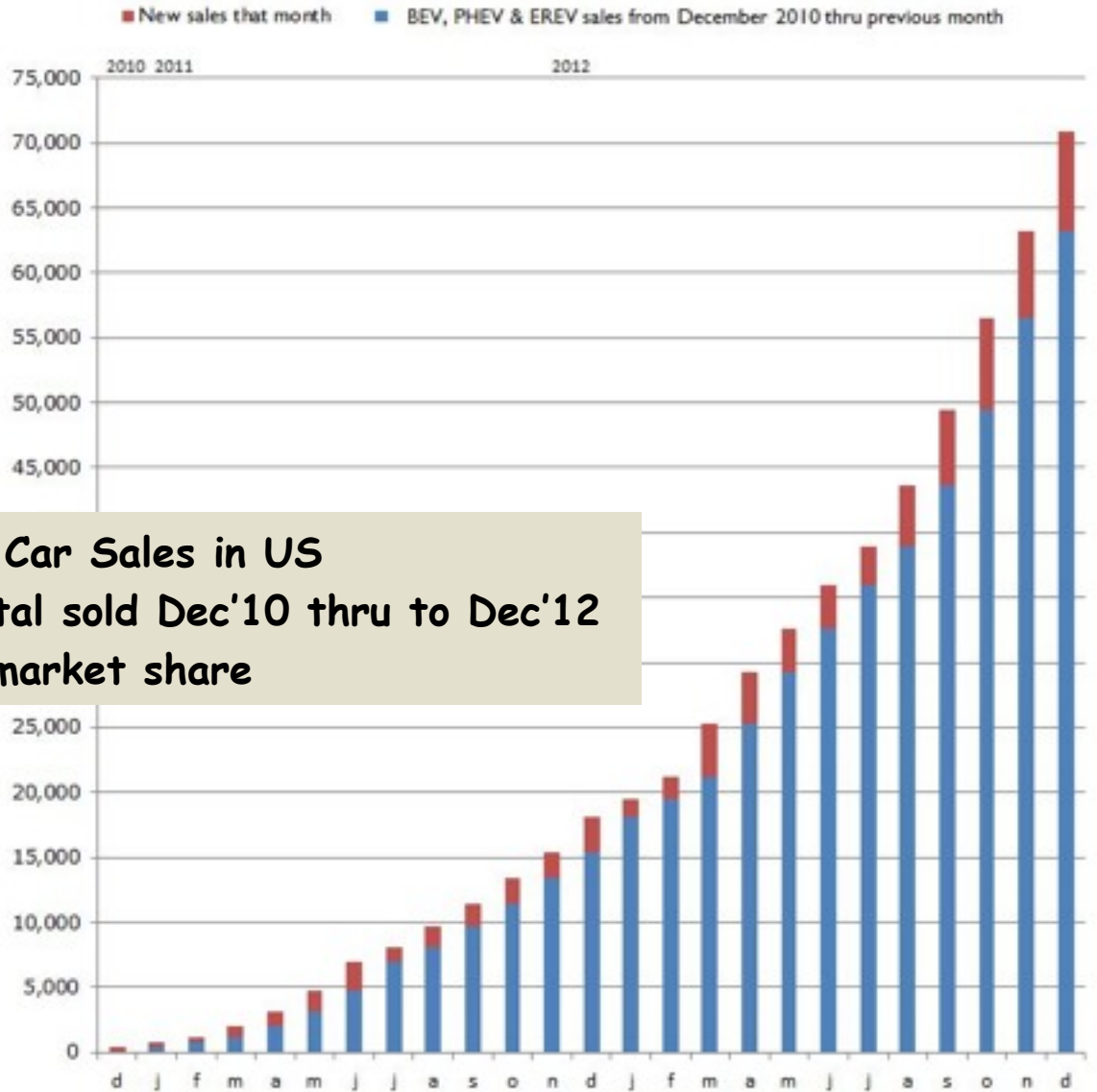


### Cumulative Plug-in Car Sales in US

= 52,835 of the 27,174,040 total sold Dec'10 thru to Dec'12  
= 0.194% of market share



### Cumulative U.S. plug-in vehicle sales



Sales figures sourced from HybridCars.com with additional input from EDTA member companies



# G2V

## NEED FAITH WHEN NUMBERS DO NOT ADD UP

Purchasers need to have the money

Purchasers care for the benefits of Evs

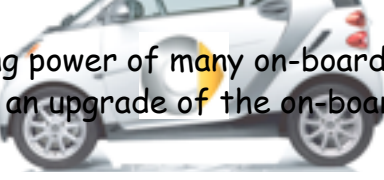
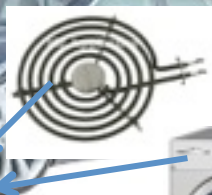
Purchasers may want the uniqueness

.... Where? ... Demographics

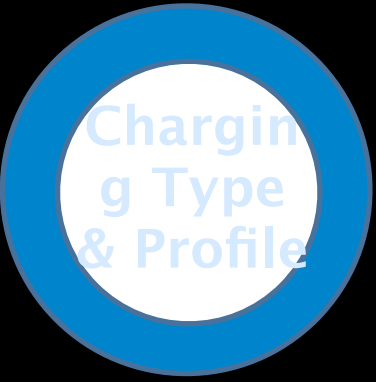
# Charging Type & Profile

| Level          | EVSE Input Voltage [V] | EVSE Maximum Input Current [A] | Charge Power From EVSE [kW] | Time for a Full Charge |            | Charge Rate (at battery or wheel) |         |
|----------------|------------------------|--------------------------------|-----------------------------|------------------------|------------|-----------------------------------|---------|
|                |                        |                                |                             | PHEV                   | EV         |                                   |         |
|                |                        |                                |                             | [hr]                   | [hr]       | [kWh/hr]                          | [km/hr] |
| Level 1 AC     | 120 VAC                | 15                             | 1.4                         | 3 to 8                 | 11 to 21   | 1.3                               | 0.12    |
|                | 120 VAC                | 20                             | 1.9                         | 2 to 6                 | 8 to 15    | 1.8                               | 0.16    |
| Level 2 AC     | 240 VAC                | 16                             | 3.3                         | 1 to 3.5               | 4.8 to 8.9 | 3.1                               | 0.28    |
|                | 240 VAC                | 32                             | 7                           | 0.6 to 1.6             | 2.3 to 4.2 | 6.7                               | 0.58    |
|                | 240 VAC                | 80                             | 20                          | 0.2 to 0.6             | 0.8 to 1.5 | 18.8                              | 1.7     |
| DC Fast Charge | 480 VAC                | 50                             | 36                          | 0.12 to 0.31           | 0.4 to 0.8 | 33.5                              | 3.0     |
|                | 480 VAC                | 165                            | 125                         | 0.03 to 0.09           | 0.1 to 0.2 | 112.5                             | 10.4    |

\*Orange section denote the maximum charging power of many on-board chargers currently available. The 2013 Nissan Leaf is scheduled to include an upgrade of the on-board charger to the 32A current limit.





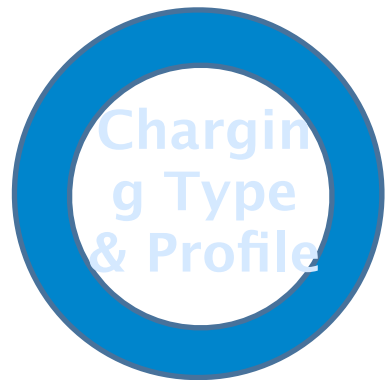


Charging Type  
& Profile

*G2V*



*~2.3kW*



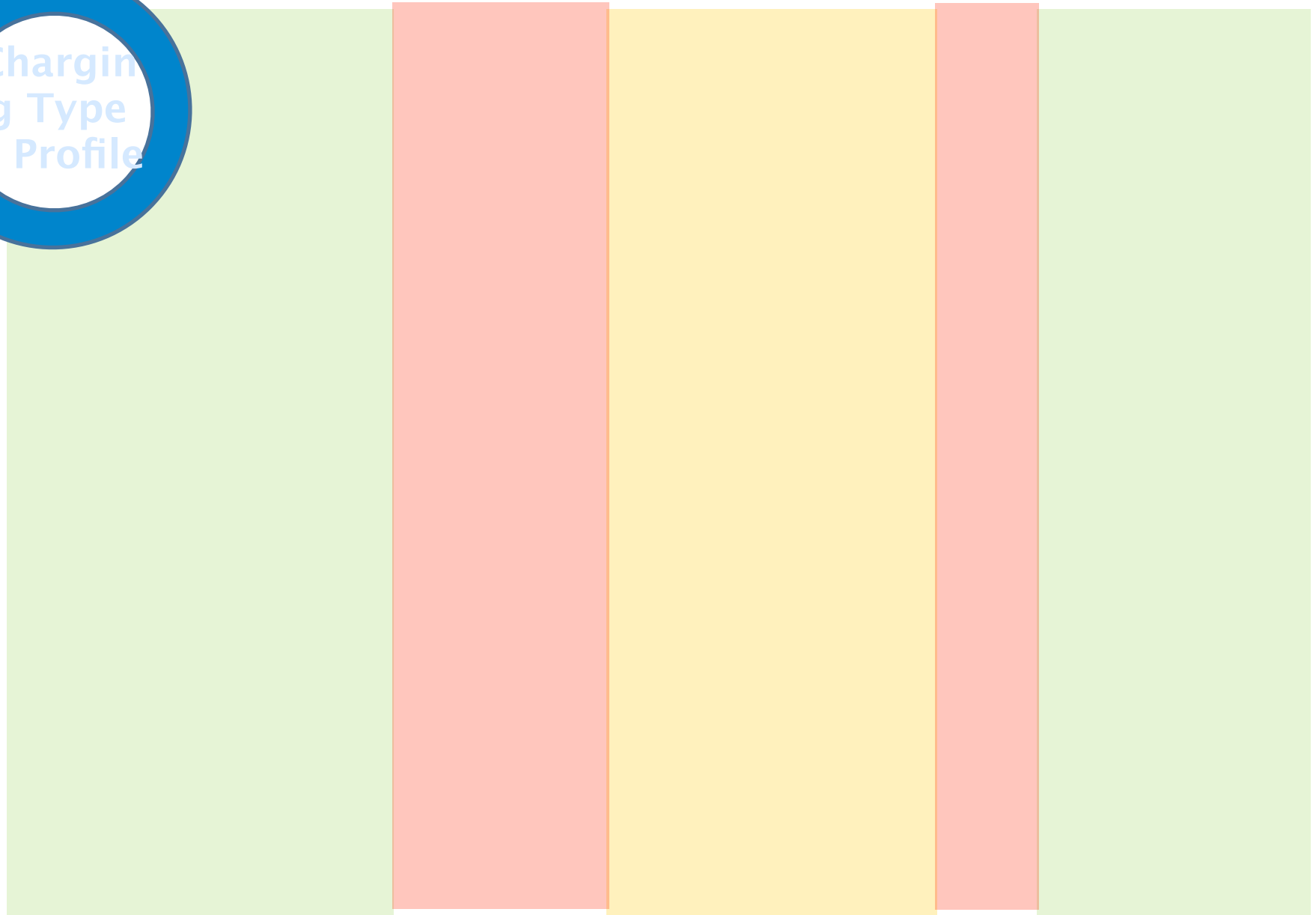


Chargin  
g Type  
& Profile





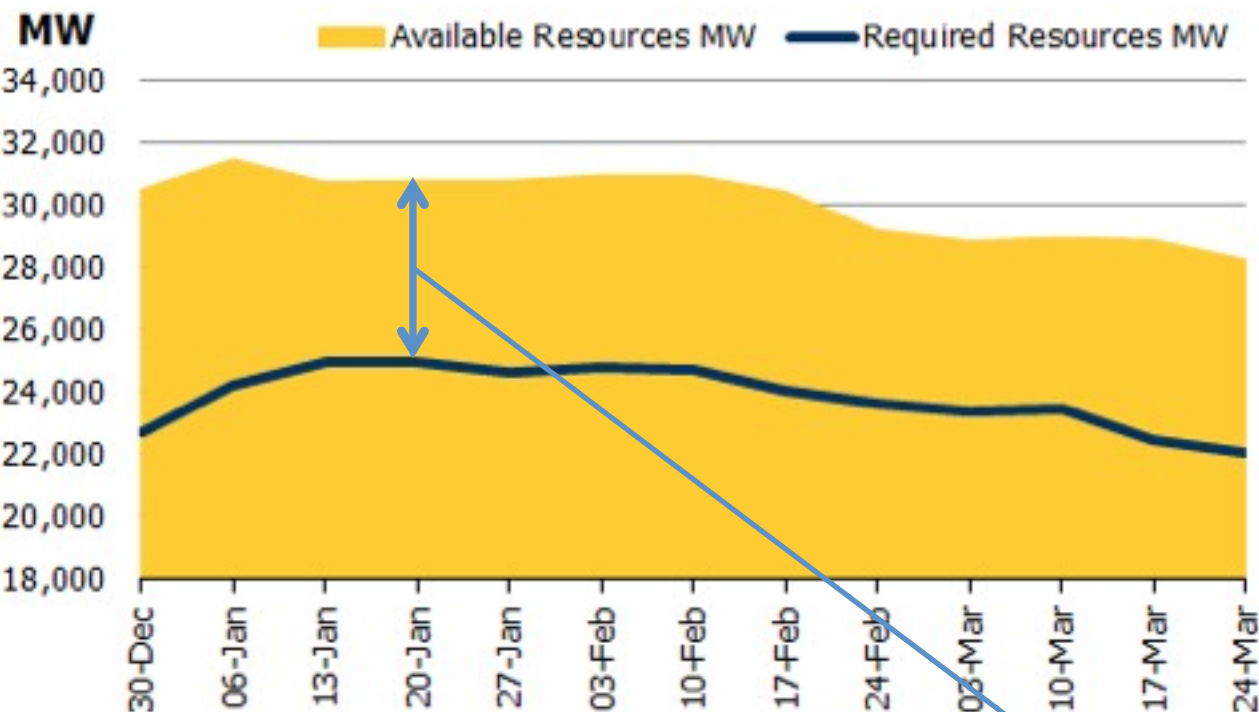
Charging Type  
& Profile



# Supply Adequacy

## Provincial

### SUPPLY OUTLOOK - WINTER 2012/13



#### AVAILABLE GENERATION DURING SEASONAL PEAK (week of January 14)

Total Installed Resources **36,072 MW**

Outages or other reductions in capacity **6,044 MW**

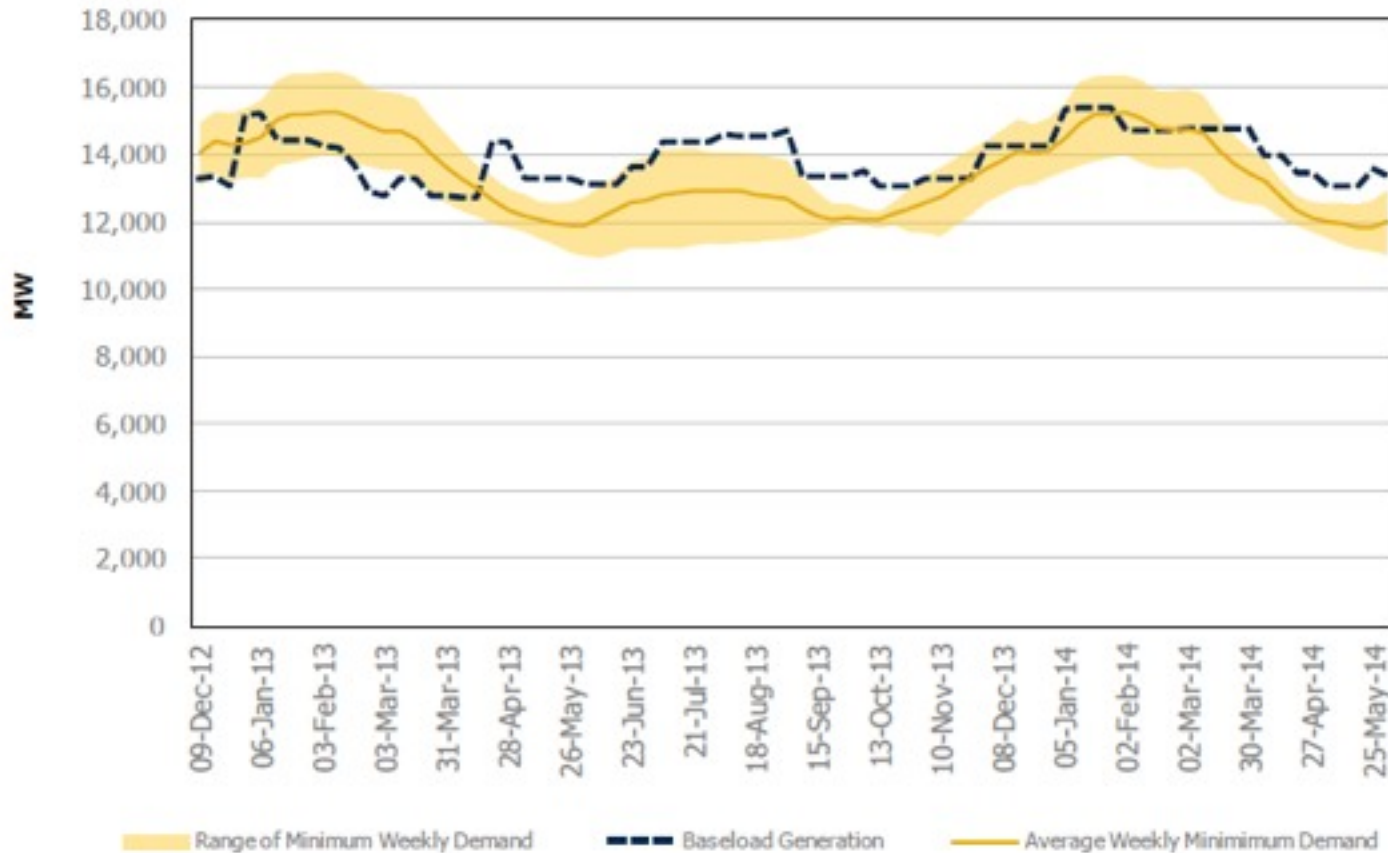
Demand Response **774 MW**

Total Available Resources **30,802 MW**

[www.ieso.ca](http://www.ieso.ca)

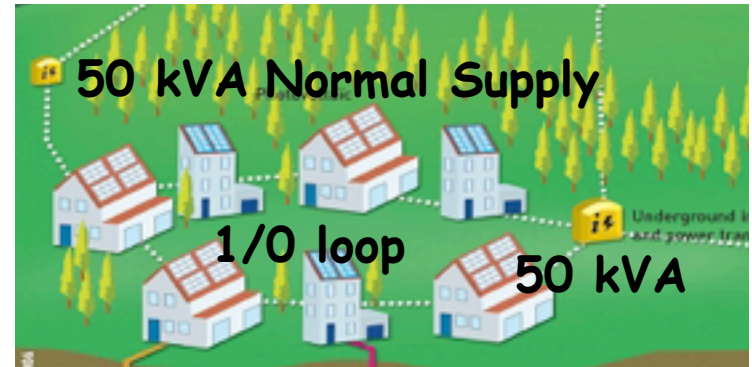
Reserve (~18-20% required)

**Figure 6.1 Minimum Ontario Demand and Baseload Generation (Includes Net Export Assumption)**





# Thermal Loading

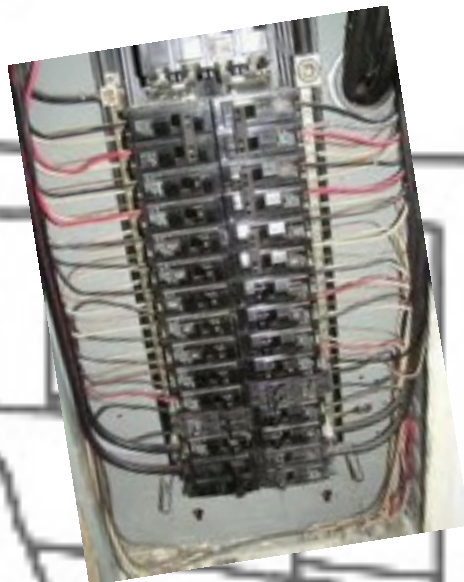


$$\begin{array}{l} \sim 2.3 \text{ kW avg} \\ \sim 5 \text{ kW pk} \end{array} * 10 = \begin{array}{l} \sim 23 \text{ kW avg} \\ \sim 50 \text{ kW pk} \end{array}$$

$$+ (\#?) * L2 @ 3.3 \text{ kW} = ? \text{ overload}$$

# Thermal Loading

Customer Premise



Thermal  
Loadin  
g

Off-peak?

|                              | EV (pure)                 | Combustion Engine      |
|------------------------------|---------------------------|------------------------|
| Fuel Economy (on the drive)  | 300Wh/km                  | 10L/100km              |
| Fuelling Inefficiency        | 15%                       | 0%                     |
| Fuel Economy (with fuelling) | 353Wh/km<br>35.3kWh/100km | 10L/100km<br>10L/100km |
| Fuel Cost \$                 | 0.100 /kWh                | \$ 1.150 /L            |
| Cost / 100km \$              | 3.53                      | \$ 11.50               |
| Equivalency Point \$         | 0.326 /kWh                | \$ 0.353 /L            |

## System Losses

Reduce "I" in a segment of conductor, reduce losses  
 $P = I^2 R$

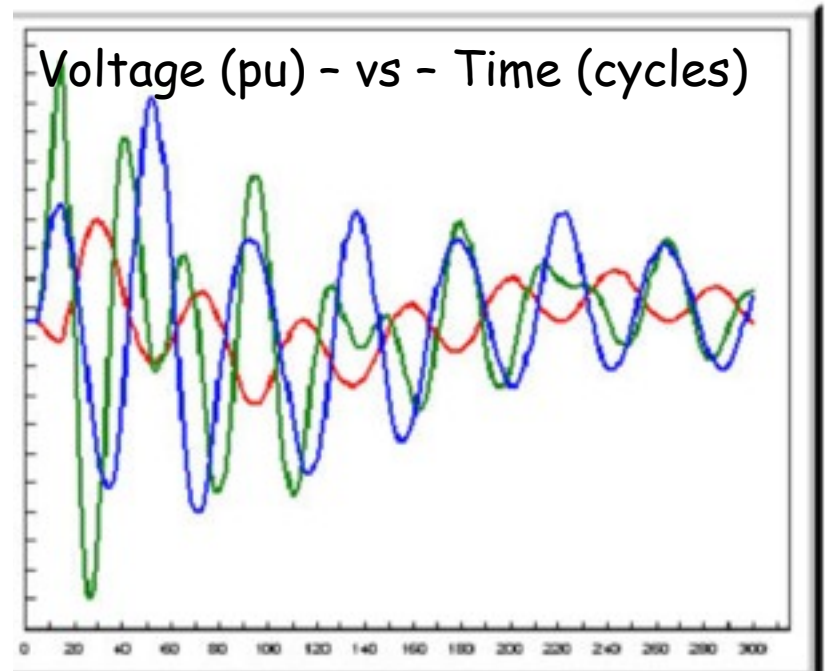
Reduce "V" by 1% reduces demand by 1% (dependent on resistive load)

Feeder imbalance

Protective devices

System supportive devices needing power

## Voltage Stability



Demand  $\gg$  Supply

Large load draw

Cycling of large loads

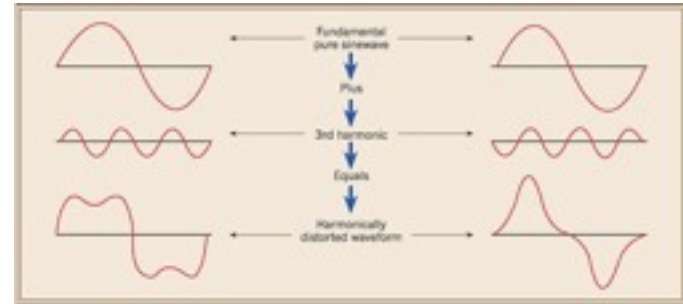


## Feeder Imbalance

In a three-phase System:  
any or each phase carries  
magnitude of current 15%  
or more than the other

Contributes to System  
Losses

## Harmonics



www.powerqualityworld.com

SAE J2894 "Power Quality  
Requirements for Electric Vehicle  
Chargers" issued 2011/12/08

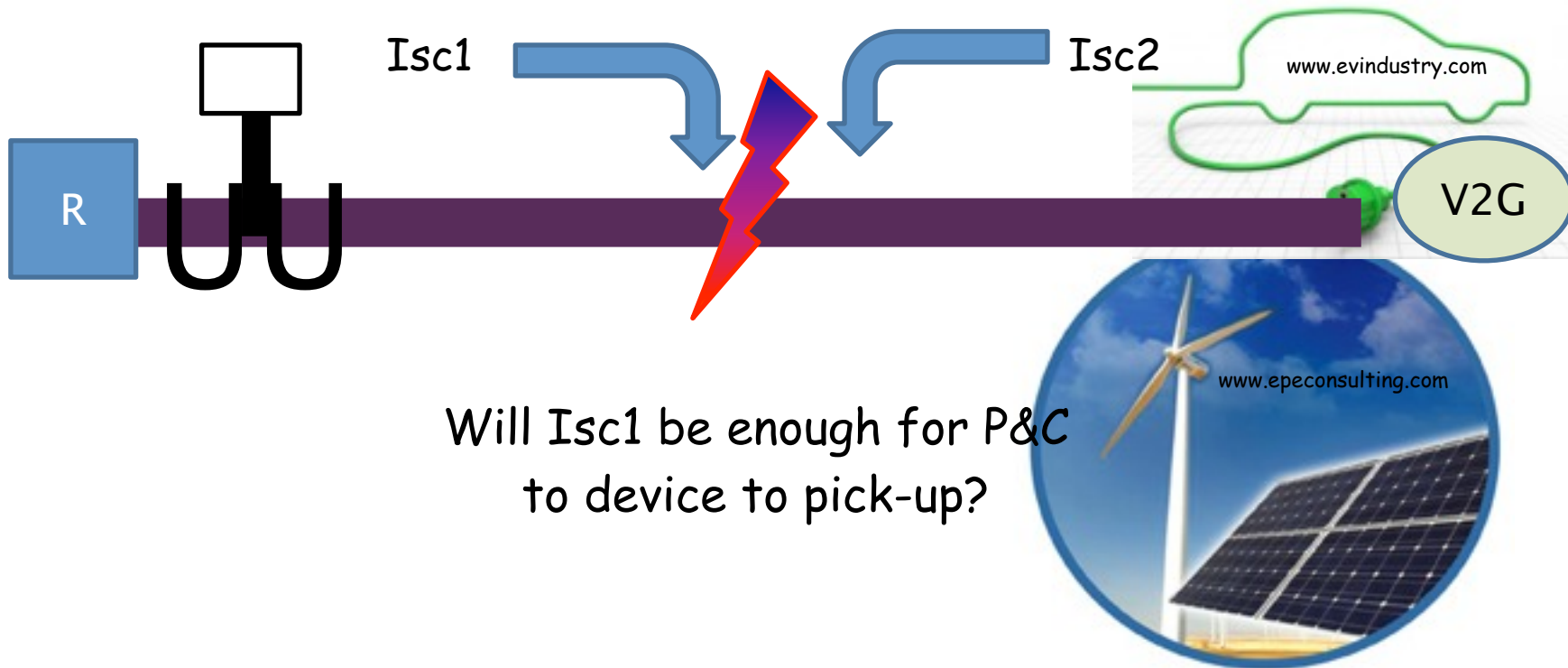
Non-compliant need study!! (THDi &  
THDv / on & off-board)

"Understanding the Grid Impacts of Plug-In  
Electric Vehicles (PEV): Phase 1 Study --  
Distribution Impact Case Studies," EPRI,  
2012/12/31

# Protection And Control

Upstream  
(Station) Source

Downstream  
(Customer) Source



Will  $I_{sc1}$  be enough for P&C  
to device to pick-up?

# V2G



- Grid Support

Micro-Grid during outage

Voltage, Frequency

Energy Storage:

Sink for excess generation

Power flow balance / ballast

- Vehicle Owner Source of Revenue

Peak shaving

Arbitrage

Supports Sustainability

- Vehicle Usability

Battery Life Degradation

Warranty

Range degradation

Range for next trip

- Actual Available Energy

Temperature Affect

State of Charge

Discharge Rate

- Availability when & where needed?

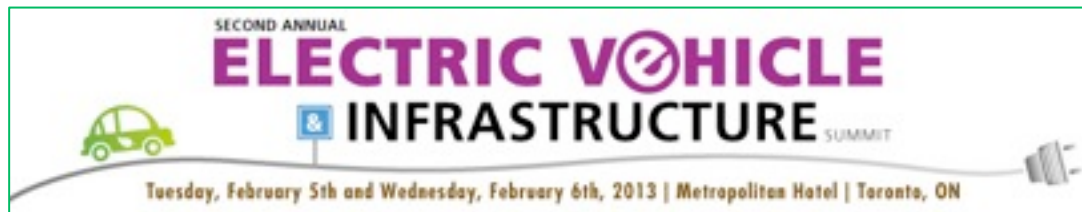
- Settlement:

Metering -- What Rate?

Process -- Who's benefactor?

- What about incapable in-service

# Upcoming Events



EVCO - meet last Monday of  
every month @ Canada Science  
& Technology Museum



IEEE Electrical Power and Energy  
Conference (EPEC) 2013  
August 21-23, 2013  
Marriott Harbourfront Hotel,  
Halifax, Nova Scotia, Canada  
<http://sites.ieee.org/epec2013/>



# Resources

Raed Abdullah, P.Eng., SMIEEE  
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w-e-mail

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[www.hydroottawa.com](http://www.hydroottawa.com)



[www.ieee.org](http://www.ieee.org)  
[www.ieeeottawa.ca](http://www.ieeeottawa.ca)  
[electricvehicle.ieee.org](http://electricvehicle.ieee.org)



Electric Mobility Canada    Mobilité électrique Canada

[www.emc-mec.ca](http://www.emc-mec.ca)



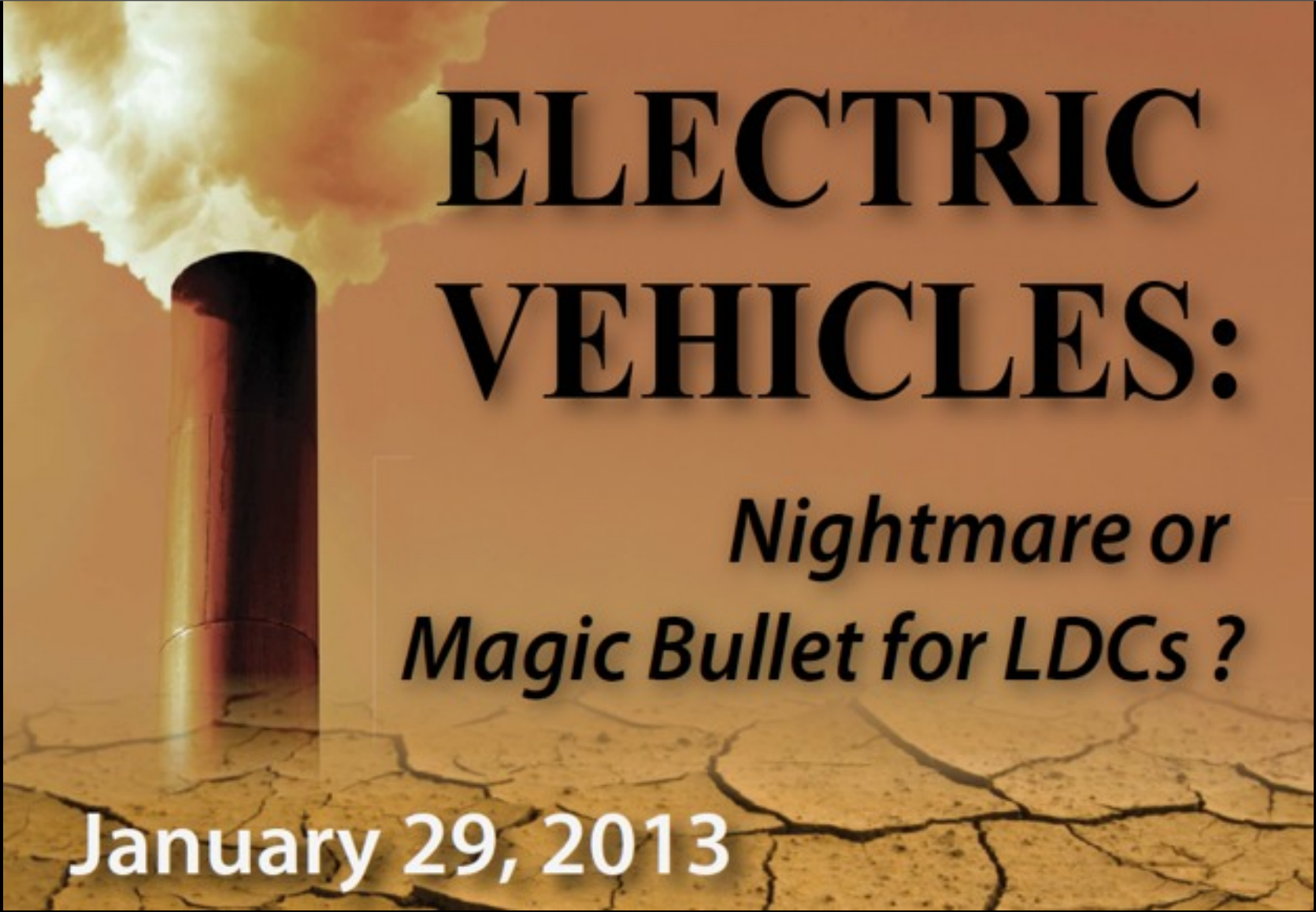
Darryl McMahon  
[www.econogics.com](http://www.econogics.com)  
"The Emperor's New  
Hydrogen Economy"



[www.sae.org](http://www.sae.org)



[evco.ca/site](http://evco.ca/site)



# ELECTRIC VEHICLES:

*Nightmare or  
Magic Bullet for LDCs ?*

January 29, 2013



**Carleton**  
UNIVERSITY



Carleton Research Unit on Innovation, Science & Environment

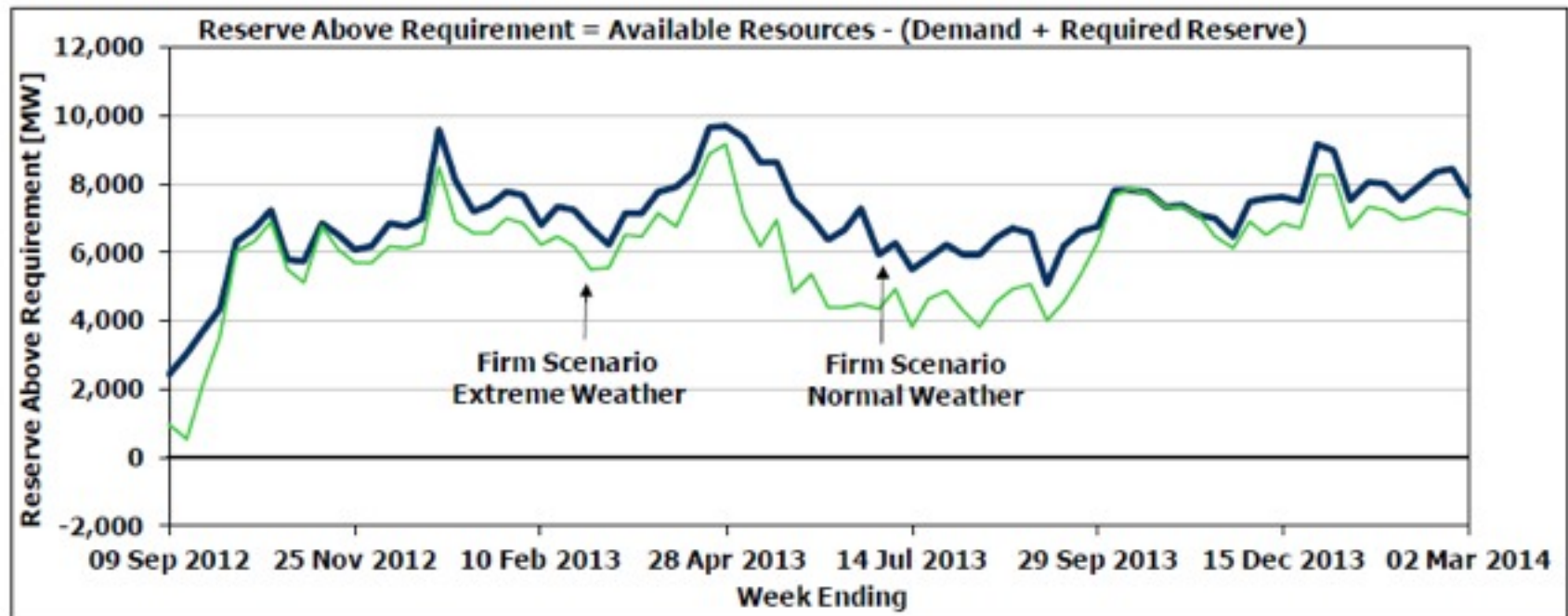


Carleton Sustainable Energy Research Centre

#### 4.4 Firm Scenario with Normal and Extreme Weather

Reserve Above Requirement levels, which represent the difference between Available Resources and Required Resources, are shown in Figure 4.2.

*Figure 4.2 Reserve Above Requirement: Firm Scenario with Normal vs. Extreme Weather*



[http://www.ieso.ca/imoweb/pubs/marketReports/18MonthOutlook\\_2012sep.pdf](http://www.ieso.ca/imoweb/pubs/marketReports/18MonthOutlook_2012sep.pdf)

**Table 4.1 Existing Generation Resources as of August 6, 2012**

| Fuel Type              | Total Installed Capacity (MW) | Forecast Capability at Winter Peak* (MW) | Number of Stations | Change in Installed Capacity (MW) | Change in Stations |
|------------------------|-------------------------------|------------------------------------------|--------------------|-----------------------------------|--------------------|
| Nuclear                | 11,446                        | 11,368                                   | 5                  | 0                                 | 0                  |
| Hydroelectric          | 7,947                         | 6,012                                    | 71                 | 0                                 | 0                  |
| Coal                   | 3,504                         | 3,136                                    | 4                  | 0                                 | 0                  |
| Oil / Gas              | 9,987                         | 9,387                                    | 29                 | 0                                 | 0                  |
| Wind                   | 1,511                         | 507                                      | 12                 | 0                                 | 0                  |
| Biomass / Landfill Gas | 122                           | 44                                       | 6                  | 0                                 | 0                  |
| Total                  | 34,517                        | 30,454                                   | 127                | 0                                 | 0                  |

\* Actual Capability may be less as a result of transmission constraints

18-Month Outlook Sep.'12 Report



**Table 4.1 Existing Generation Resources as of November 8, 2012**

| Fuel Type              | Total Installed Capacity (MW) | Forecast Capability at Winter Peak* (MW) | Number of Stations | Change in Installed Capacity (MW) | Change in Stations |
|------------------------|-------------------------------|------------------------------------------|--------------------|-----------------------------------|--------------------|
| Nuclear                | 12,998                        | 10,552                                   | 5                  | 1,552                             | 0                  |
| Hydroelectric          | 7,947                         | 5,659                                    | 71                 | 0                                 | 0                  |
| Coal                   | 3,293                         | 2,983                                    | 3                  | -211                              | -1                 |
| Oil / Gas              | 9,987                         | 9,145                                    | 29                 | 0                                 | 0                  |
| Wind                   | 1,511                         | 507                                      | 12                 | 0                                 | 0                  |
| Biomass / Landfill Gas | 122                           | 44                                       | 6                  | 0                                 | 0                  |
| Total                  | 35,858                        | 28,890                                   | 126                | 1,341                             | -1                 |

\* Actual Capability may be less as a result of transmission constraints

## 18-Month Outlook Dec.'12 Report

**Table 4.4 Summary of Available Resources**

| Notes | Description                        | Winter Peak 2013 |                  | Summer Peak 2013 |                  | Winter Peak 2014 |                  |
|-------|------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
|       |                                    | Firm Scenario    | Planned Scenario | Firm Scenario    | Planned Scenario | Firm Scenario    | Planned Scenario |
| 1     | Installed Resources (MW)           | 36,020           | 36,020           | 36,020           | 36,316           | 36,020           | 36,549           |
| 2     | Imports (MW)                       | 0                | 0                | 0                | 0                | 0                | 0                |
| 3     | Total Resources (MW)               | 36,020           | 36,020           | 36,020           | 36,316           | 36,020           | 36,549           |
| 4     | Total Reductions in Resources (MW) | 4,617            | 4,617            | 5,544            | 5,776            | 4,387            | 4,808            |
| 5     | Demand Measures (MW)               | 1,141            | 1,315            | 1,141            | 1,505            | 1,141            | 1,505            |
| 6     | Available Resources (MW)           | 32,544           | 32,719           | 31,617           | 32,045           | 32,774           | 33,246           |

**Notes to Table 4.4:**

1. Installed Resources: This is the total generation capacity assumed to be installed at the time of the summer and winter peaks.
2. Imports: The amount of external capacity considered to be delivered to Ontario.
3. Total Resources: The sum of Installed Resources (line 1) and Imports (line 2).
4. Total Reductions in Resources: Represent the sum of deratings, planned outages, limitations due to transmission constraints, generation constraints due to transmission outages/limitations and allowance for capability levels below rated installed capacity.
5. Demand Measures: The amount of demand available to be reduced.
6. Available Resources: Equals Total Resources (line 3) minus Total Reductions in Resources (line 4) plus Demand Measures (line 5).

### **Utilities (municipal & regional)**

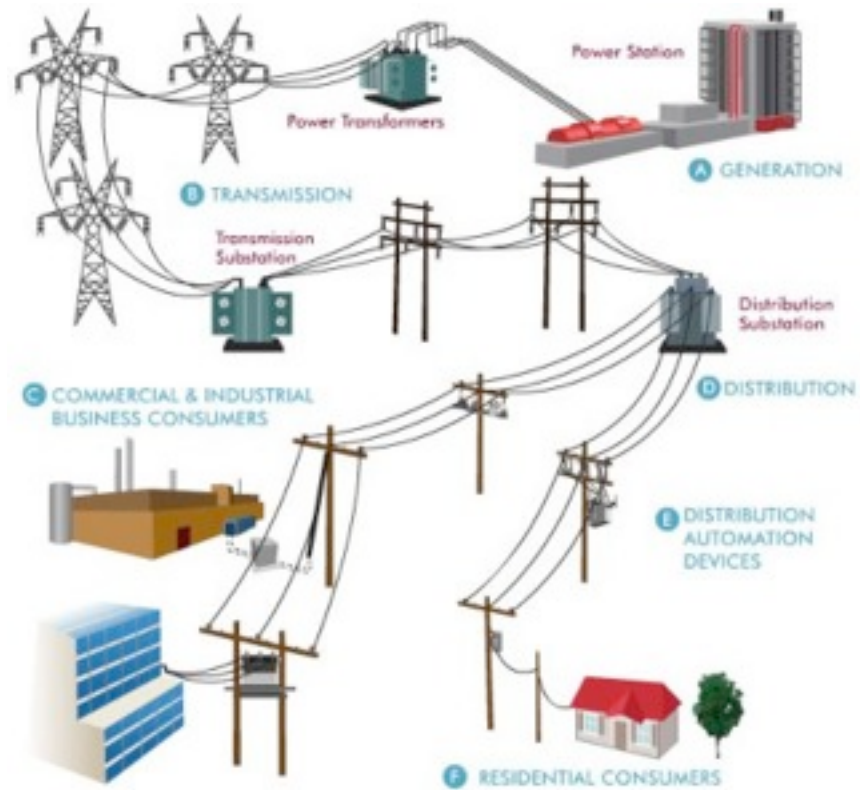
- Provide incentives and services for home/commercial charging installations (i.e. provide no/low cost installation financed thru monthly utility bill)
- Provide free charging or low-cost Plug-in vehicle rates (3–4 cents/kWh off peak)
- Provide “green” renewable electricity options
- Commit to fleet purchases (15 high-profile vehicles)

### **Large Local Employers (as Early Adopters)**

- Major corporations provide work-place charging (25 park/charge spots) and employee vehicle purchase incentives (add'l \$1000/vehicle)
- Commit to corporate fleet purchases (20 vehicles)

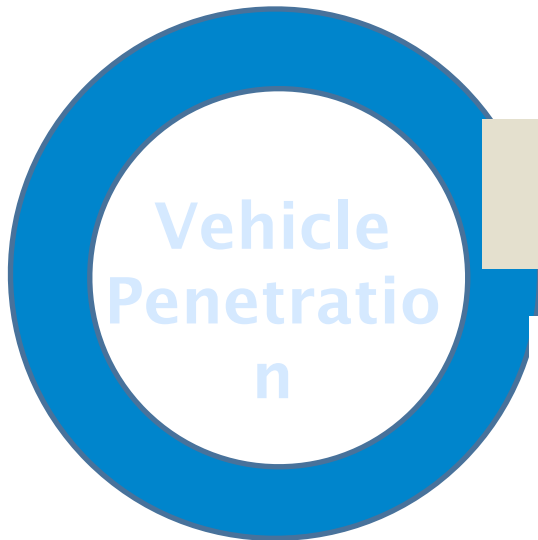
### **Universities**

- Provide campus charging and free parking (10 distributed charging locations); Commit/fund university fleet purchases (5 high-profile vehicles)





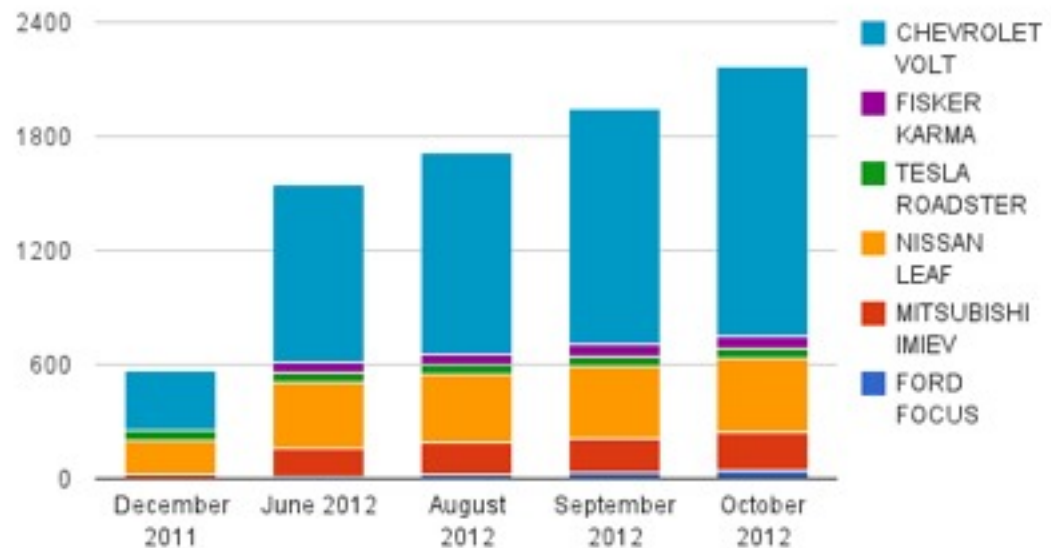
# G2V



## Cumulative Plug-in Car Registration in Canada Up to Oct. 2012



Registered Plug-In Vehicles In Canada



All data on this page is from Polk & Associates and is received under paid license by



Table 5.6: Selected Types of Vehicles by Model Year, 2009

| Vehicle Class             | Total            | Model Years    |                |                |                |                |                |                |                |                |                |                  |
|---------------------------|------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------------------|
|                           |                  | 2010           | 2009           | 2008           | 2007           | 2006           | 2005           | 2004           | 2003           | 2002           | 2001           | 2000 and earlier |
| Passenger                 | 6,488,233        | 159,108        | 423,390        | 489,943        | 511,095        | 470,168        | 485,861        | 424,718        | 505,526        | 480,345        | 405,584        | 2,132,495        |
| Motorcycle                | 200,810          | 471            | 10,526         | 16,709         | 16,998         | 16,087         | 13,884         | 12,166         | 14,591         | 11,215         | 10,397         | 77,766           |
| Moped                     | 1,471            | 0              | 8              | 7              | 20             | 97             | 294            | 78             | 37             | 67             | 223            | 640              |
| Commercial*               | 1,312,868        | 24,442         | 70,871         | 91,841         | 95,756         | 88,050         | 87,182         | 84,889         | 89,489         | 75,249         | 69,594         | 535,505          |
| Bus                       | 32,290           | 780            | 2,735          | 2,229          | 2,100          | 2,901          | 2,269          | 2,793          | 2,152          | 1,758          | 2,108          | 10,465           |
| Motorized Snow Vehicle    | 316,562          | 3,470          | 6,959          | 6,251          | 8,549          | 9,287          | 8,686          | 8,938          | 9,171          | 10,053         | 7,093          | 238,105          |
| Off-Road Vehicle          | 341,811          | 997            | 12,169         | 20,993         | 26,035         | 23,480         | 23,575         | 25,164         | 20,429         | 16,396         | 18,766         | 153,807          |
| <b>Total</b>              | <b>8,694,045</b> | <b>189,268</b> | <b>526,658</b> | <b>627,973</b> | <b>660,553</b> | <b>610,070</b> | <b>621,751</b> | <b>558,746</b> | <b>641,395</b> | <b>595,083</b> | <b>513,765</b> | <b>3,148,783</b> |
| 20% of Passenger Vehicles | 1,297,647        |                |                |                |                |                |                |                |                |                |                |                  |

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**TABLE 18**  
**PERSONAL INCOME PER CAPITA, MAJOR CANADIAN CITIES (CMAs)**

| CMA             |          | 2009     | 2010     | 2011     | 2012f    | 2013f    | 2014f    | 2015f    | 2016f    |
|-----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Toronto         |          | \$38,299 | \$39,360 | \$40,046 | \$40,715 | \$42,195 | \$43,571 | \$44,812 | \$46,049 |
|                 | % change | -1.9%    | 2.8%     | 1.7%     | 1.7%     | 3.6%     | 3.3%     | 2.8%     | 2.8%     |
| Montréal        |          | \$34,722 | \$35,666 | \$36,008 | \$36,451 | \$37,572 | \$38,663 | \$39,962 | \$41,206 |
|                 | % change | -0.8%    | 2.7%     | 1.0%     | 1.2%     | 3.1%     | 2.9%     | 3.4%     | 3.1%     |
| Vancouver       |          | \$36,470 | \$37,261 | \$38,261 | \$39,088 | \$40,253 | \$41,494 | \$42,685 | \$43,883 |
|                 | % change | -3.0%    | 2.2%     | 2.7%     | 2.2%     | 3.0%     | 3.1%     | 2.9%     | 2.8%     |
| Ottawa-Gatineau |          | \$41,924 | \$42,903 | \$43,595 | \$44,263 | \$45,421 | \$46,907 | \$48,380 | \$49,904 |
|                 | % change | 0.3%     | 2.3%     | 1.6%     | 1.5%     | 2.6%     | 3.3%     | 3.1%     | 3.2%     |
| Calgary         |          | \$52,366 | \$53,834 | \$55,227 | \$56,635 | \$58,397 | \$60,420 | \$62,405 | \$64,220 |
|                 | % change | -5.5%    | 2.8%     | 2.6%     | 2.5%     | 3.1%     | 3.5%     | 3.3%     | 2.9%     |
| Edmonton        |          | \$44,920 | \$46,594 | \$48,998 | \$50,126 | \$51,571 | \$53,195 | \$54,856 | \$56,389 |
|                 | % change | -4.5%    | 3.7%     | 5.2%     | 2.3%     | 2.9%     | 3.1%     | 3.1%     | 2.8%     |
| Canada          |          | \$36,486 | \$37,563 | \$38,595 | \$39,500 | \$40,825 | \$42,166 | \$43,467 | \$44,760 |
|                 | % change | -1.0%    | 3.0%     | 2.7%     | 2.3%     | 3.4%     | 3.3%     | 6.5%     | 6.2%     |

Source: The Conference Board of Canada, Metropolitan Outlook, Spring 2012

(f) = Forecast

Note: Personal income figures, unlike those for GDP, are not adjusted for inflation

[http://ottawa.ca/sites/ottawa.ca/files/attachments/ottpage/adr\\_2011\\_en\\_0.pdf](http://ottawa.ca/sites/ottawa.ca/files/attachments/ottpage/adr_2011_en_0.pdf)



**TABLE 34****ROYAL BANK HOUSING AFFORDABILITY INDEX****PERCENTAGE OF HOUSEHOLD INCOME REQUIRED TO AFFORD EACH TYPE OF DWELLING**

| <b>Detached Bungalow</b>   | <b>Toronto</b> | <b>Montreal</b> | <b>Vancouver</b> | <b>Ottawa</b> | <b>Calgary</b> | <b>Canada</b> |
|----------------------------|----------------|-----------------|------------------|---------------|----------------|---------------|
| 2006 average               | 43.2           | 35.5            | 67.8             | 30.1          | 37.3           | 39.1          |
| 2007 average               | 45.0           | 36.2            | 70.9             | 31.4          | 42.9           | 41.0          |
| 2008 average               | 53.2           | 40.5            | 75.8             | 43.0          | 46.5           | 44.3          |
| 2009 average               | 47.5           | 37.6            | 65.5             | 39.3          | 36.2           | 39.8          |
| 2010 average               | 48.3           | 41.5            | 71.2             | 39.6          | 36.9           | 41.1          |
| 2011 Q1                    | 47.5           | 43.1            | 72.1             | 39.0          | 35.9           | 40.5          |
| 2011 Q2                    | 51.9           | 42.6            | 92.5             | 41.2          | 37.1           | 43.3          |
| 2011 Q3                    | 52.1           | 40.9            | 90.6             | 40.8          | 37.6           | 42.7          |
| <b>2011 Q4</b>             | <b>52.2</b>    | <b>40.1</b>     | <b>86.0</b>      | <b>40.9</b>   | <b>36.7</b>    | <b>42.2</b>   |
| <b>Standard Two Storey</b> |                |                 |                  |               |                |               |
| 2006 average               | 49.3           | 45.6            | 72.8             | 35.5          | 39.1           | 44.6          |
| 2007 average               | 51.9           | 46.4            | 74.0             | 36.9          | 44.4           | 46.3          |
| 2008 average               | 63.4           | 51.2            | 84.3             | 44.5          | 47.8           | 50.1          |
| 2009 average               | 56.6           | 47.2            | 72.6             | 40.7          | 37.6           | 45.4          |
| 2010 average               | 57.8           | 51.3            | 79.9             | 41.3          | 38.4           | 47.1          |
| 2011 Q1                    | 55.6           | 53.7            | 80.4             | 40.9          | 36.8           | 46.2          |
| 2011 Q2                    | 61.4           | 55.0            | 95.5             | 43.1          | 38.5           | 49.3          |
| 2011 Q3                    | 61.3           | 52.2            | 94.4             | 42.9          | 38.2           | 48.8          |
| <b>2011 Q4</b>             | <b>61.3</b>    | <b>50.2</b>     | <b>92.3</b>      | <b>43.1</b>   | <b>37.8</b>    | <b>48.1</b>   |
| <b>Standard Condo</b>      |                |                 |                  |               |                |               |
| 2006 average               | 29.1           | 29.9            | 34.4             | 21.1          | 23.2           | 27.4          |
| 2007 average               | 31.1           | 30.1            | 35.9             | 22.4          | 27.6           | 28.8          |
| 2008 average               | 36.1           | 33.1            | 43.4             | 28.2          | 29.7           | 30.1          |
| 2009 average               | 32.2           | 30.9            | 37.8             | 26.0          | 22.9           | 27.4          |
| 2010 average               | 32.2           | 33.9            | 40.5             | 27.5          | 23.0           | 28.2          |
| 2011 Q1                    | 31.4           | 34.1            | 40.1             | 27.0          | 22.2           | 27.7          |
| 2011 Q2                    | 34.2           | 32.8            | 47.1             | 28.3          | 23.0           | 29.2          |
| 2011 Q3                    | 34.3           | 32.6            | 47.2             | 28.2          | 23.2           | 29.0          |
| <b>2011 Q4</b>             | <b>33.9</b>    | <b>31.3</b>     | <b>44.8</b>      | <b>28.5</b>   | <b>22.5</b>    | <b>28.5</b>   |

Source: Royal Bank of Canada, *Housing Trends and Affordability* newsletter

The Royal Bank's Housing Affordability Index measures the proportion of pre-tax household income required to service the cost of a mortgage, including principal and interest, property taxes and utilities, based on a 25% down payment and 25-year mortgage at a fixed five-year rate, for the average price of the four house types listed above on the resale market. The bank discontinued their Affordability Index tracking for Standard Townhouse in 2010.