



Atmospheric Icing Effects on Wind Energy Production in Canada

Winterwind 2013

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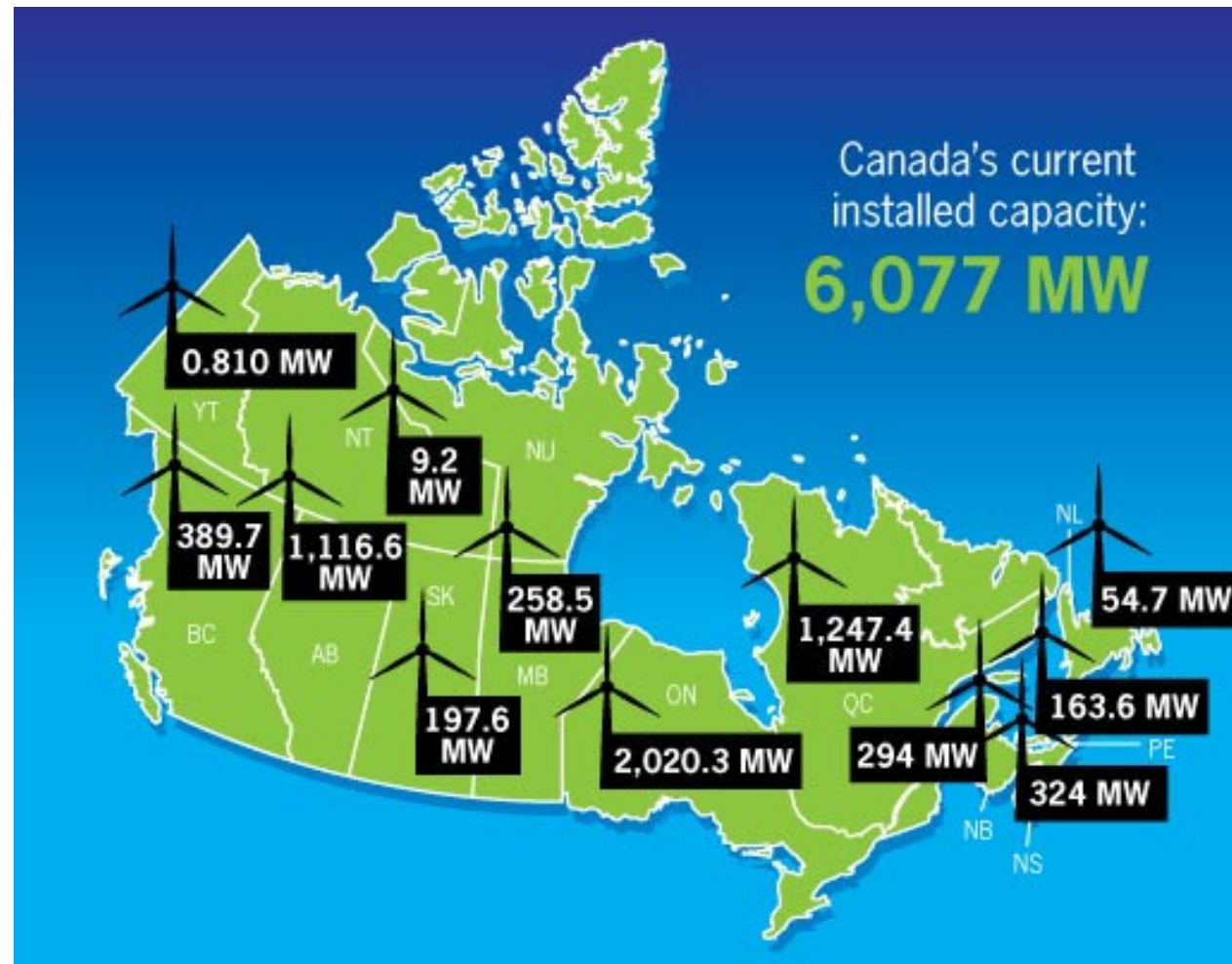


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Canada's Current Installed Capacity



Source: www.canwea.ca

- About 0.8 GW of new wind energy capacity was added in 2012
- 2.3 % of Canada's total electricity demand
- 5,000 MW of wind energy projects planned to be built over the next 5 years

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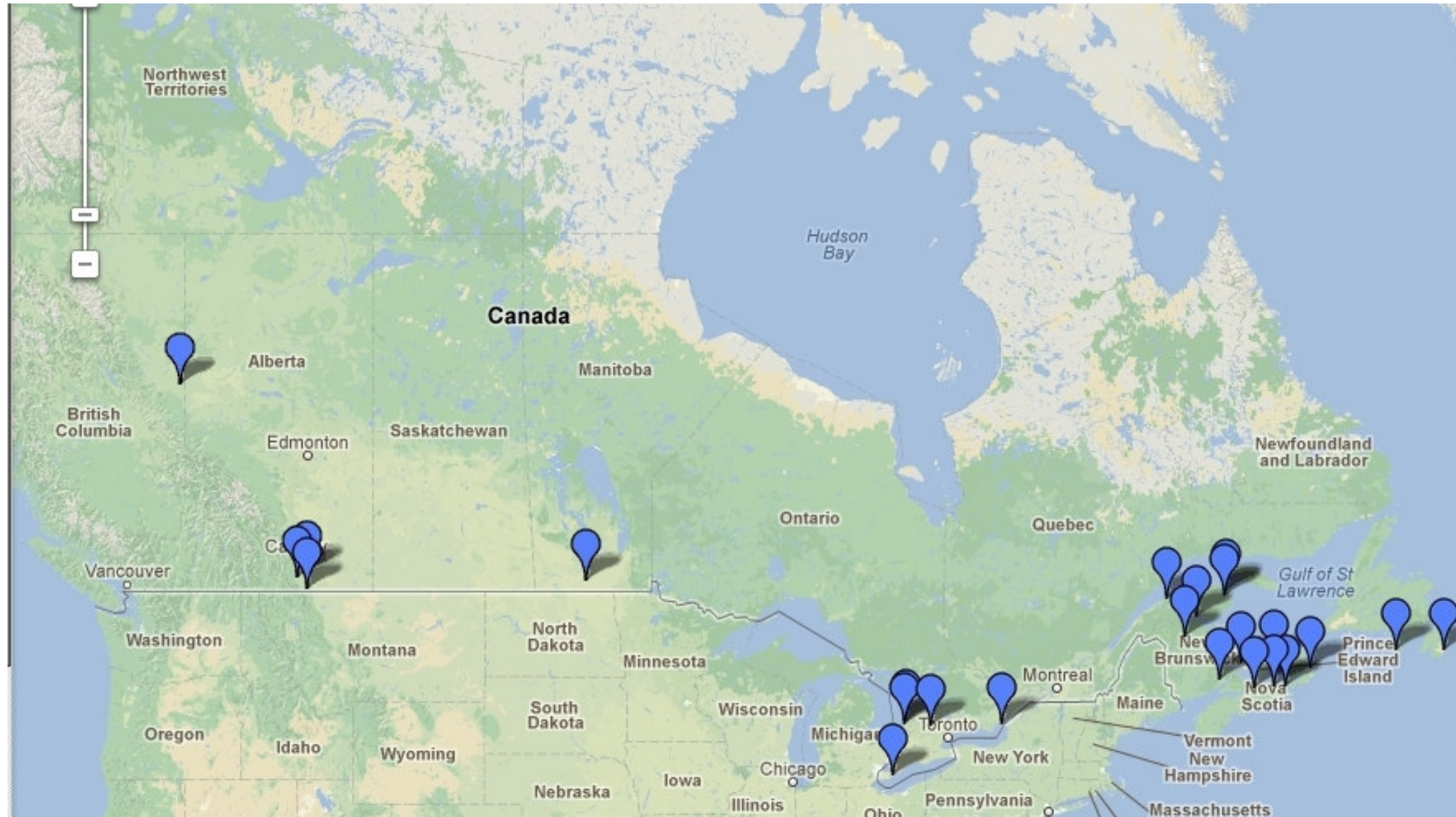
Wind Energy Cold Climate Project

- Objective of this project
 - Evaluate the magnitude and impact of cold climate conditions on Canadian wind farms
- Cold climate issues
 - Cold air temperatures
 - Atmospheric icing
- Impact of atmospheric icing on wind turbine
 - Production losses
 - Turbine loads
 - Safety

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Location of the 24 Wind Farms Surveyed Across Canada



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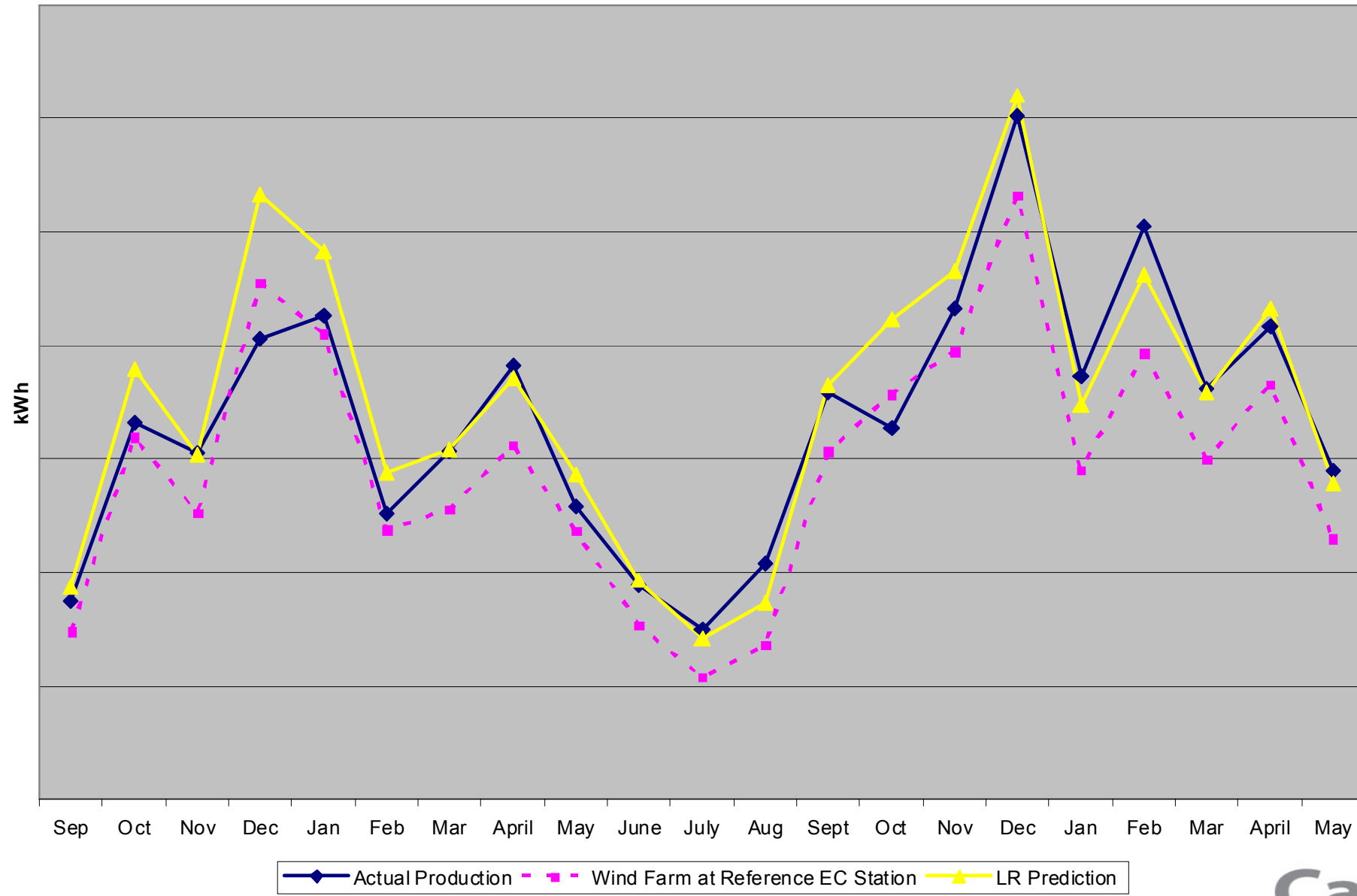
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Estimating Reference Wind Energy Production

- Use wind data from Environment Canada weather station
- Run simulations using a wind energy software
 - Use specific wind turbine information (power curve, cut-in, cut-out)
 - Take into consideration variation in air density
- Use measure-correlate-predict (MCP) algorithm to determine the reference production level
 - The learning period of the MCP is based on months free of cold climate events

Typical Production and Reference Level



Calculating the Losses

- Subtracting the actual production (blue line) from the reference production level (yellow line)
- Calculated only for the reference winter
 - November 2010 to April 2011
- Negative result is assigned a value of zero
- Losses are calculated for the reference year
 - May 2010 to April 2011 inclusively
- Results for the wind farms under review are extended for all existing and future wind farms in Canada
- Losses also expressed in terms of \$ and GHGe
 - Evaluated as per regional electricity portfolio profile

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Cold Climate Related Losses

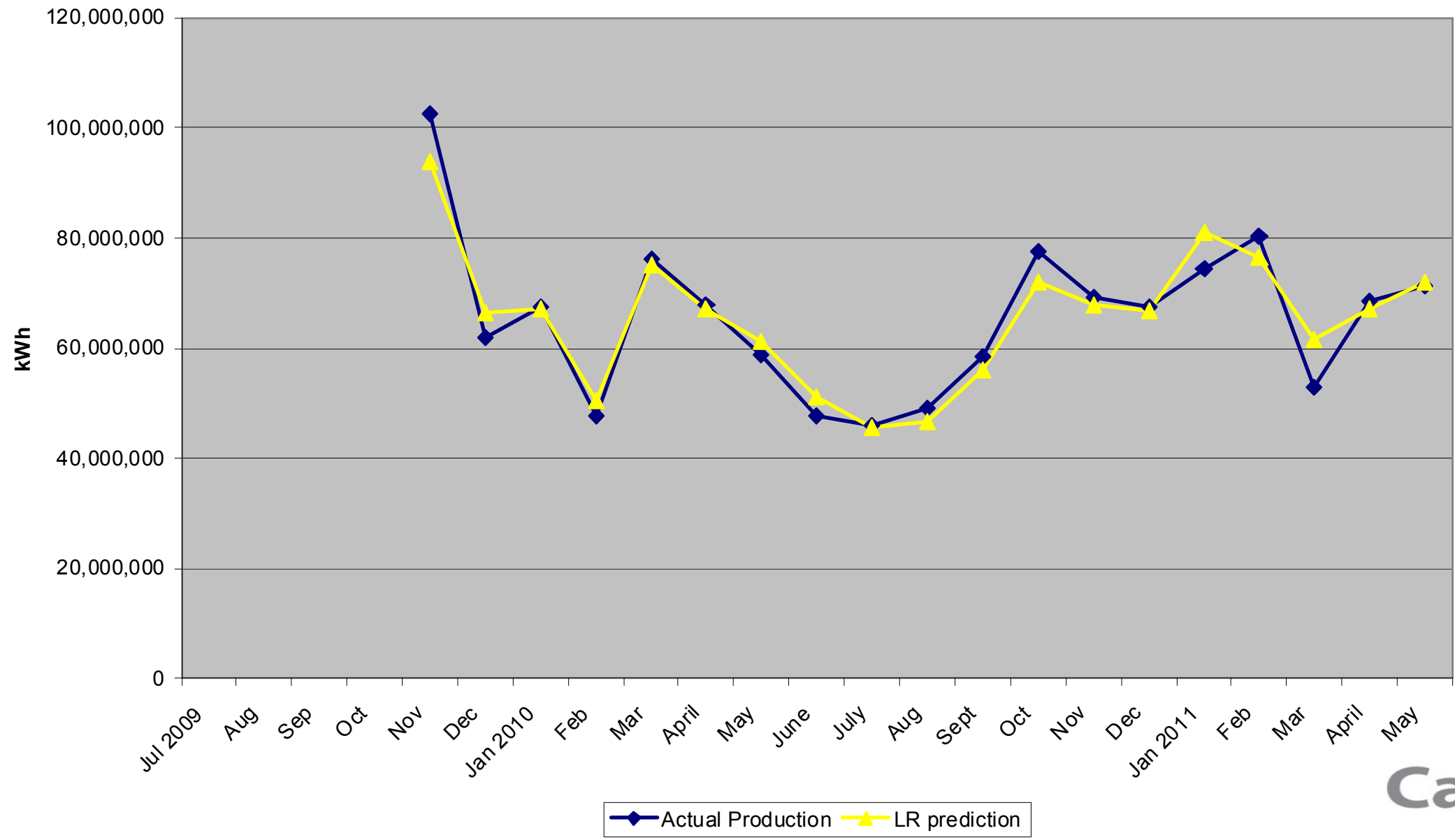
| Region | Production Losses | |
|----------|-------------------|-------------|
| | Ref. Year | Ref. Winter |
| AB + MB | 3.2% | 5.7% |
| ON | 3.5% | 5.7% |
| QC | 7.4% | 12.4% |
| NB + NS | 15.7% | 26.5% |
| PEI + NL | 3.4% | 5.8% |

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Alberta & Manitoba

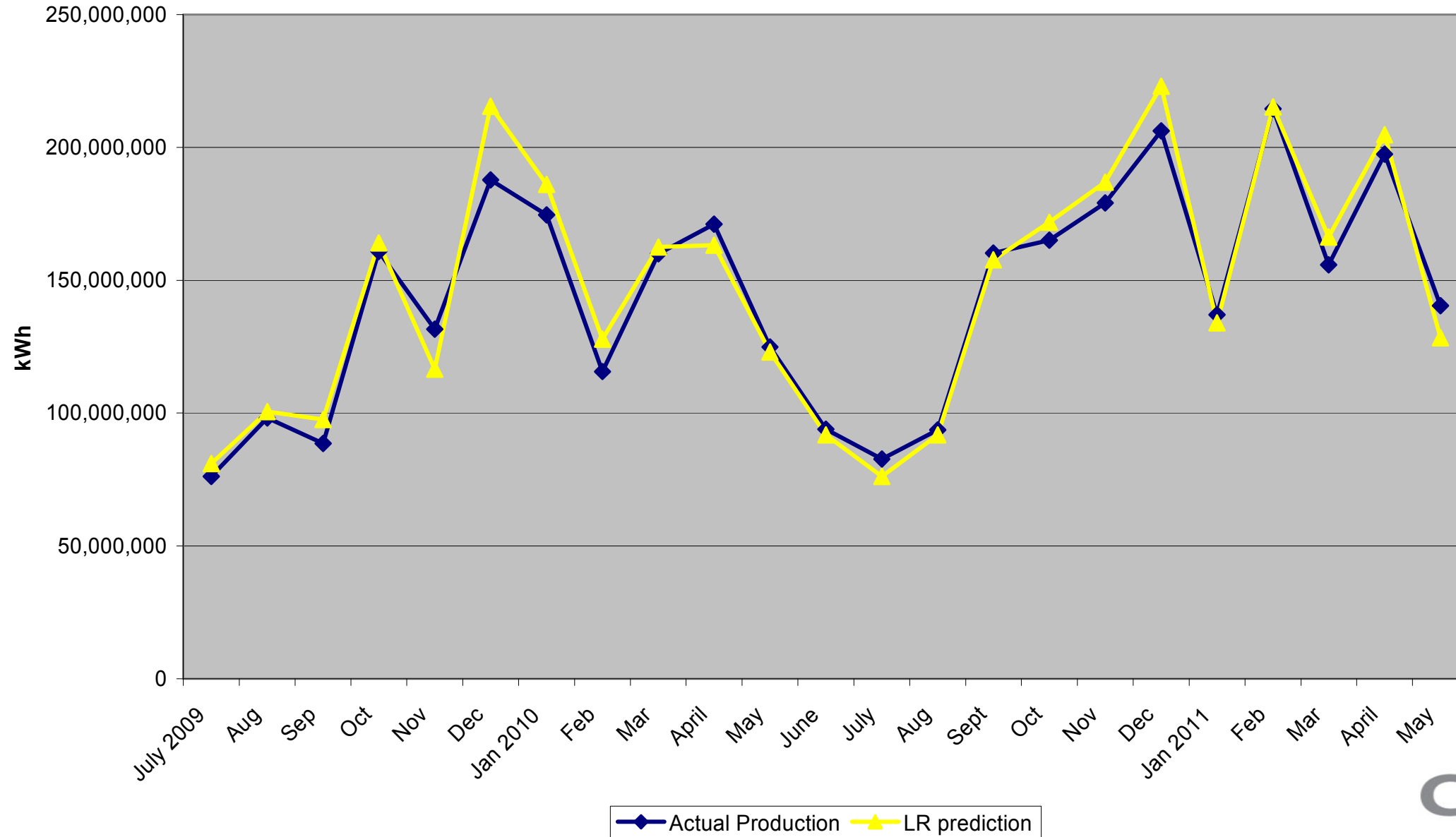
AB & MB



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Ontario

Ontario



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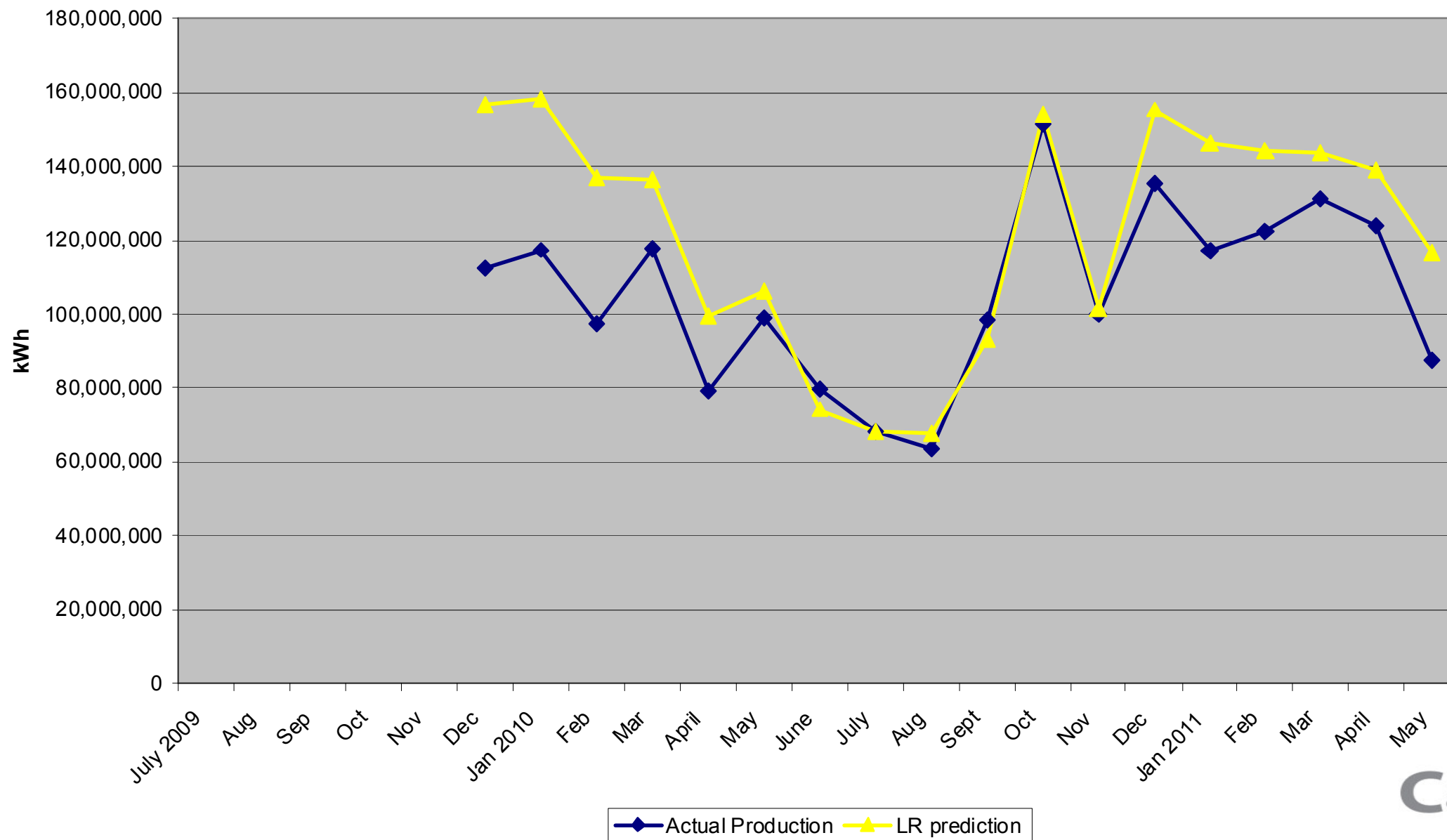
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Québec

Québec



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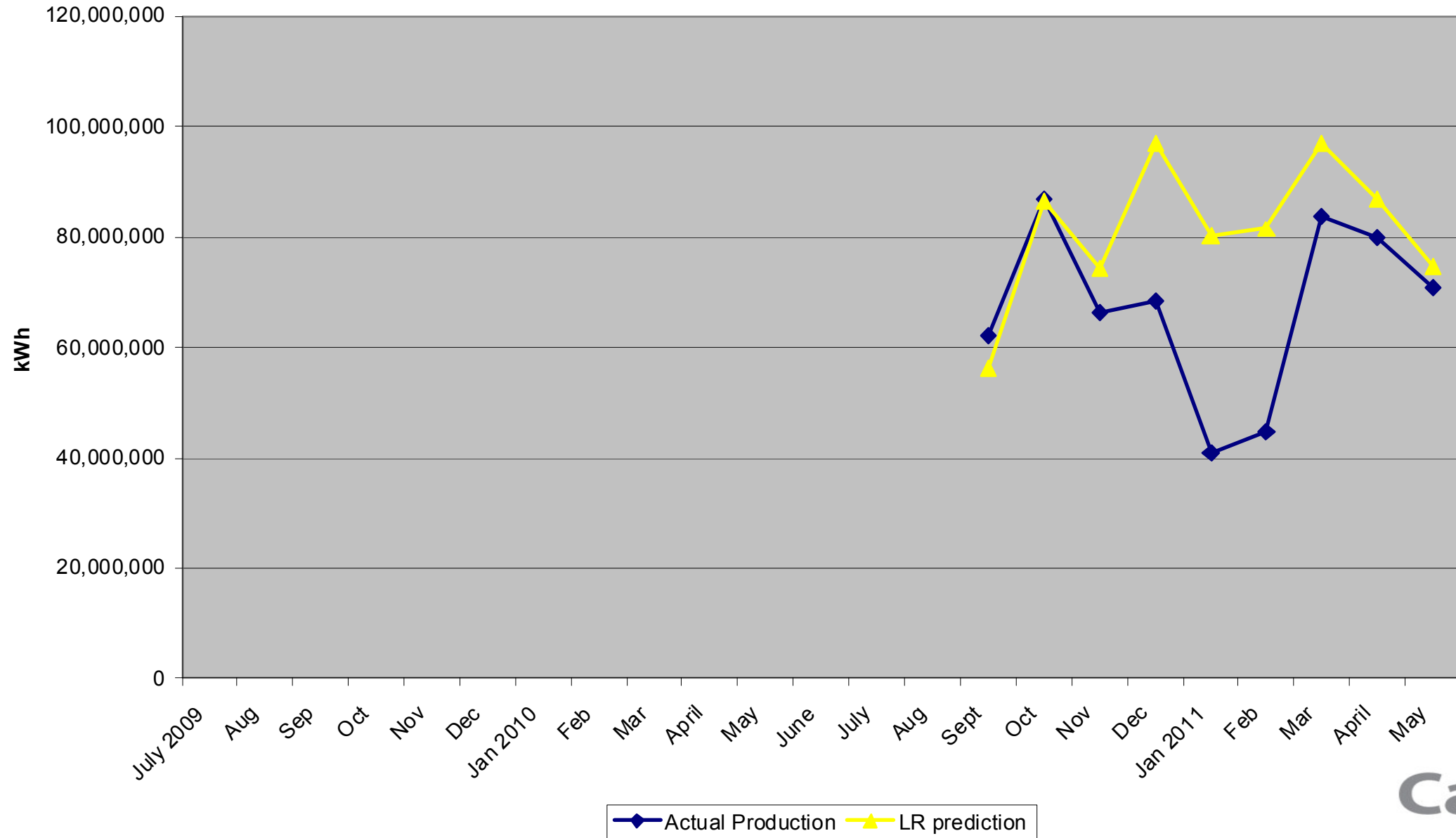


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New Brunswick & Nova Scotia NB & NS



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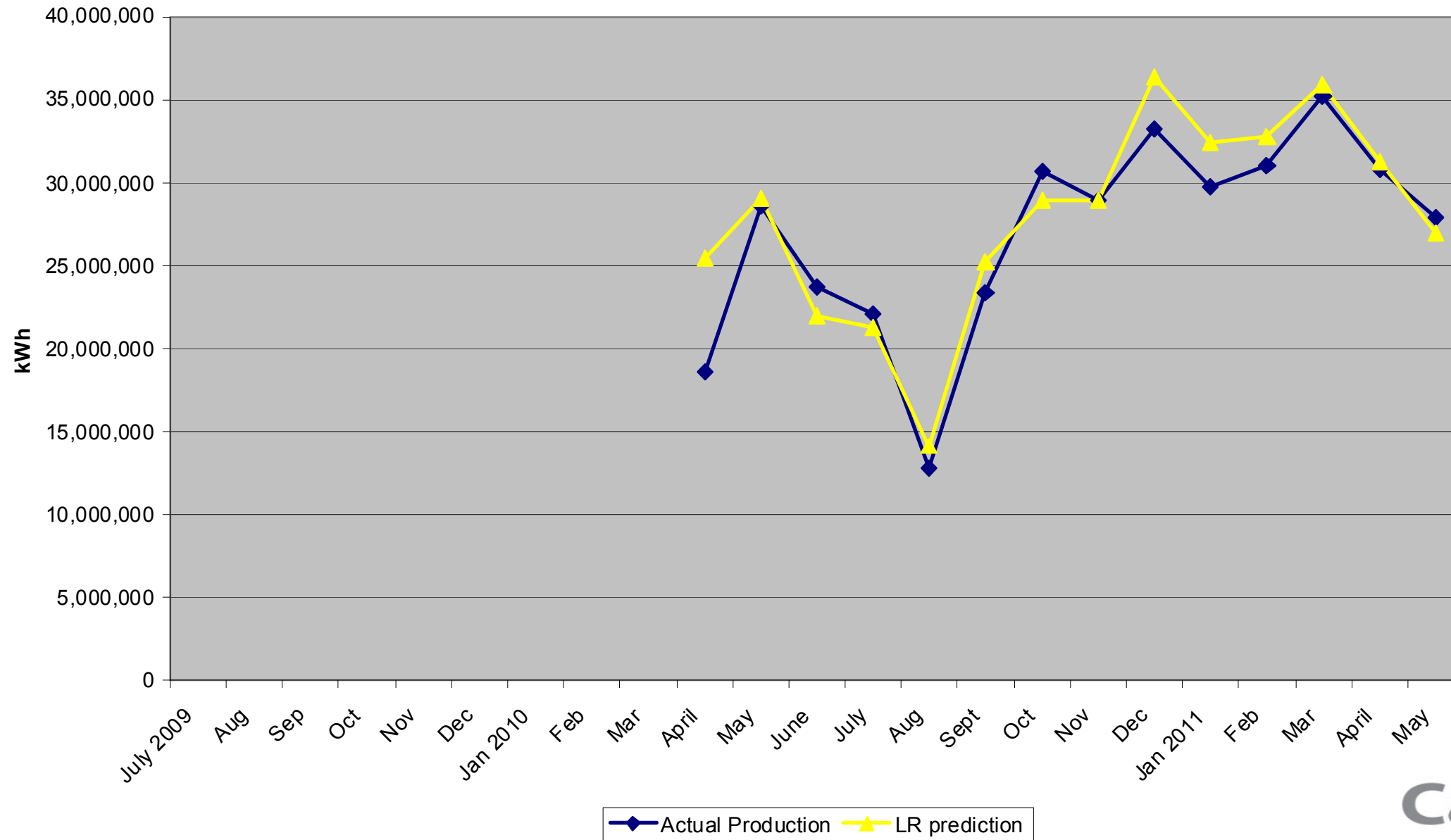


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Prince Edward Island & Newfoundland



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Remarks & Observations

- A review of 8 prefeasibility studies of the wind farms revealed that they had all underestimated the presence and impact of atmospheric icing
- Eastern Canada most affected
- Cold climate losses are observed even for wind farms whose elevation is relatively low (less than 100 meter)

Production Losses for Existing and Future Wind Farms in Canada

| | Planned Capacity (MW) | Annual Production w/ Cold Climate | Annual Cold Climate Production Loss | | Annual Cold Climate Loss (\$) | Annual Cold Climate Loss (tons CO2 eq) |
|--|-----------------------|-----------------------------------|-------------------------------------|--------------|-------------------------------|--|
| | | (MWh) | (MWh) | (%) | | |
| Existing wind farms (in operation by the end of 2011) | 5260 | 14,284,490 | 1,009,626 | 6.60% | \$ 99,880,577 | 305,449 |
| Future wind farms (under construction and planned, 2012 onwards) | 9804 | 26,624,557 | 1,143,787 | 4.12% | \$ 92,287,584 | 480,171 |
| Total for Canada | 15064 | 40,909,048 | 2,153,413 | 5.00% | \$ 192,168,161 | 785,620 |

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Thank You !

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