



From Utility to Developer:

## Simulator-Based Testing Needs Driven by Hydro-Québec's Emerging Wind Developer Role

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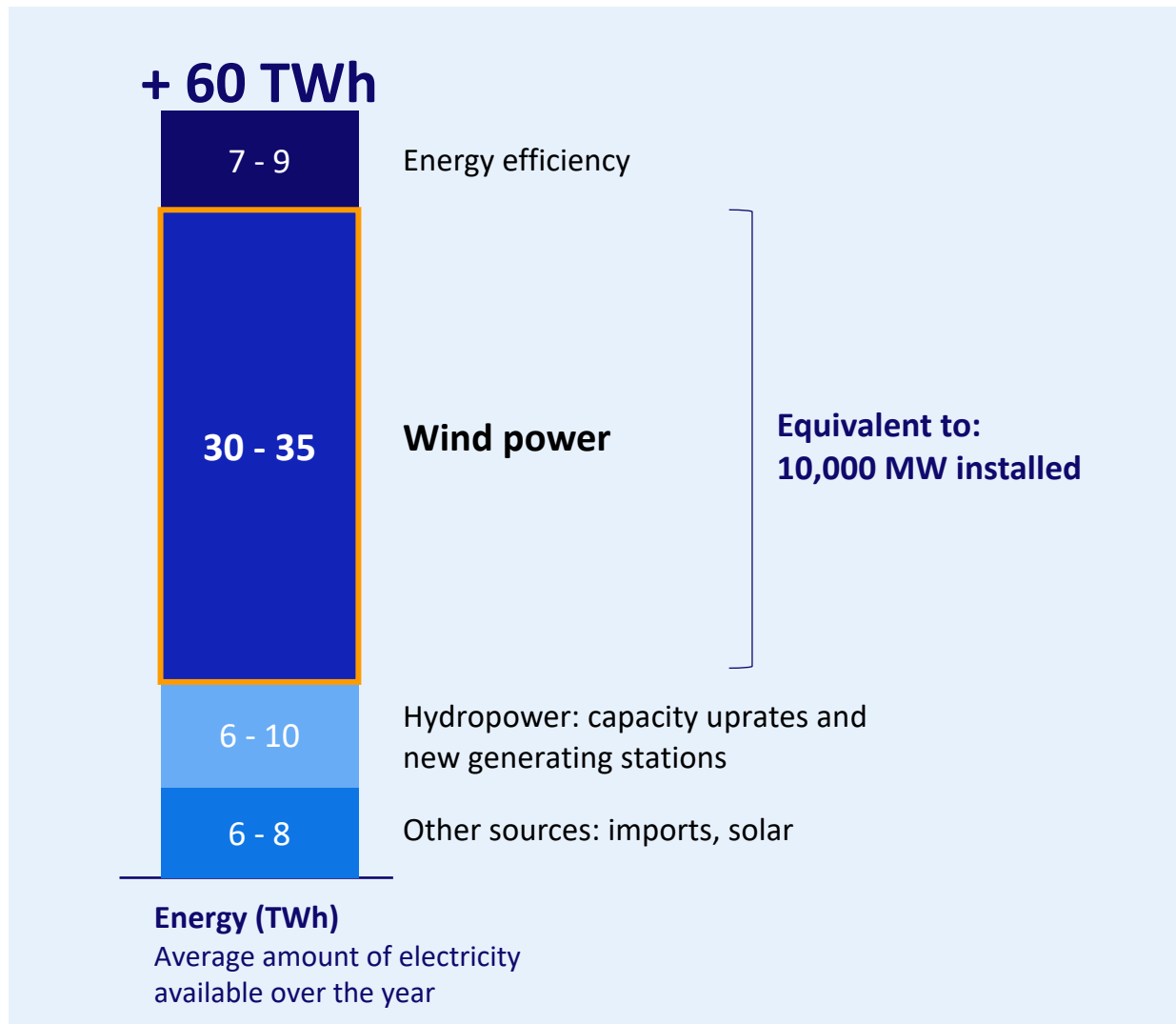


From Utility to Developer

# Agenda

1. New Generation Capacity Required
2. Wind Energy Advantages
3. Wind Development Strategy and Portfolio
4. Mapping of Structuring Zones
5. Integration Challenges
6. Integration Studies
7. Benefits of PHIL testing

# New Generation Capacity Is Required

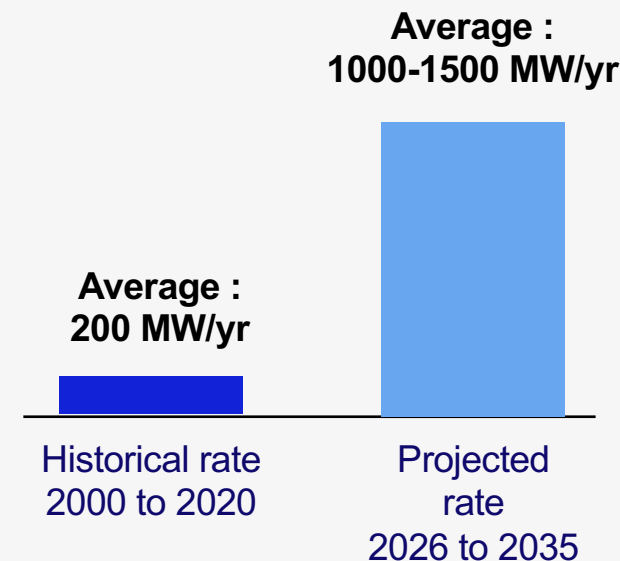


  
**+ 4 000 MW**  
Installed in the last 20 years

↓

  
**+ 10 000 MW**  
To be installed in the next 10 years

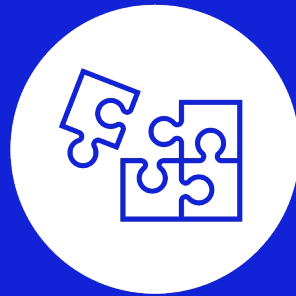
**Evolution of the annual pace of new wind capacity deployment in Québec**



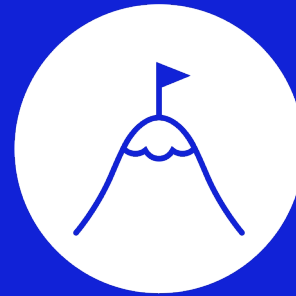
# Wind Energy Offers Several Distinct Advantages for Québec



Declining wind turbine manufacturing costs in recent years



Complementarity with hydropower and reservoir storage



Strong correlation between wind energy production and winter peak demand in the Québec market

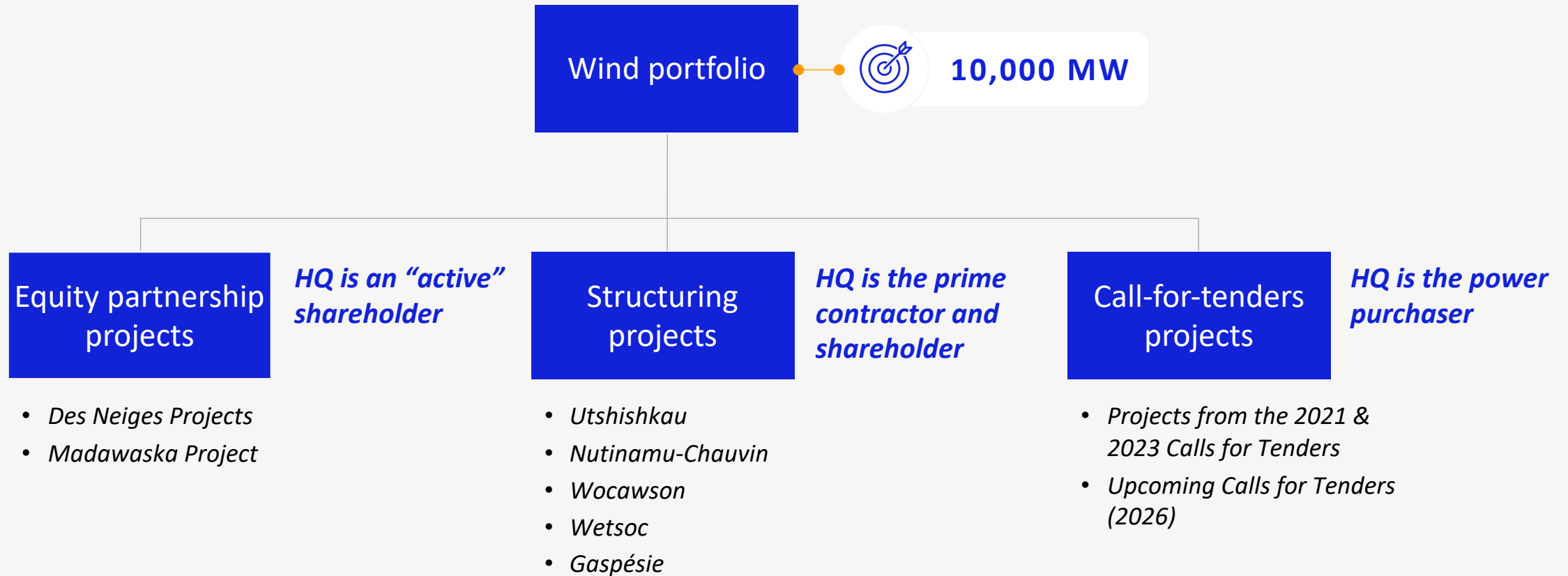


A generation source that can be deployed relatively quickly

# Hydro-Québec's Wind Development Strategy Provides for the Coexistence of Two Complementary Models

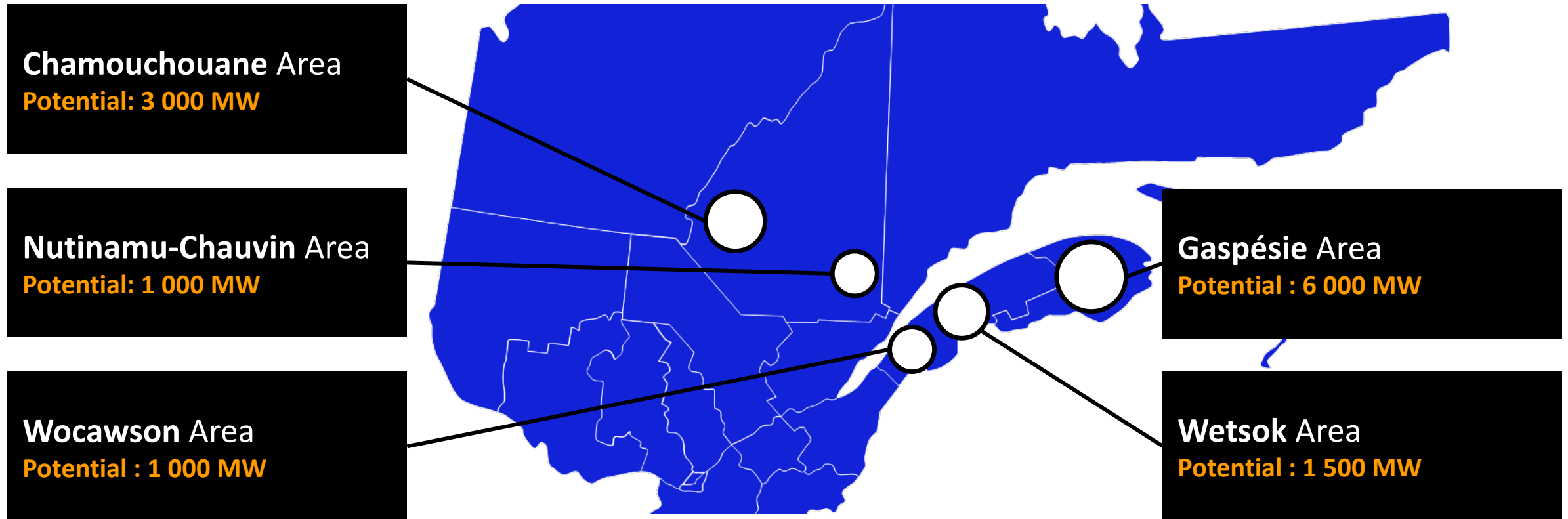
|                                | Call for Tenders<br>Typical project scale                                                                                                                               | Structuring Zones<br>Large-scale projects                                                                                                                                         |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Development areas</b>       | <ul style="list-style-type: none"> <li>• Areas with residual capacity on the transmission system</li> <li>• Primarily located in Southern Québec</li> </ul>             | <ul style="list-style-type: none"> <li>• Establishment of structuring development zones</li> <li>• Alignment with the evolution of the electricity transmission system</li> </ul> |
| <b>Indicative project size</b> | <ul style="list-style-type: none"> <li>• Projects under 350 MW</li> </ul>                                                                                               | <ul style="list-style-type: none"> <li>• Capacity potentially exceeding 1,000 MW</li> </ul>                                                                                       |
| <b>Hydro-Québec's Role</b>     | <ul style="list-style-type: none"> <li>• Purchaser of electricity</li> <li>• Identification of infrastructure enabling the interconnection of new wind farms</li> </ul> | <ul style="list-style-type: none"> <li>• Purchaser of electricity</li> <li>• Prime contractor</li> <li>• Equity partner</li> </ul>                                                |
| <b>Industry partners' Role</b> | <ul style="list-style-type: none"> <li>• Prime contractor</li> <li>• Equity partner</li> </ul>                                                                          | <ul style="list-style-type: none"> <li>• Providers of expertise (technical, equity participation)</li> </ul>                                                                      |

# Three Project Programs Make Up the Wind Portfolio



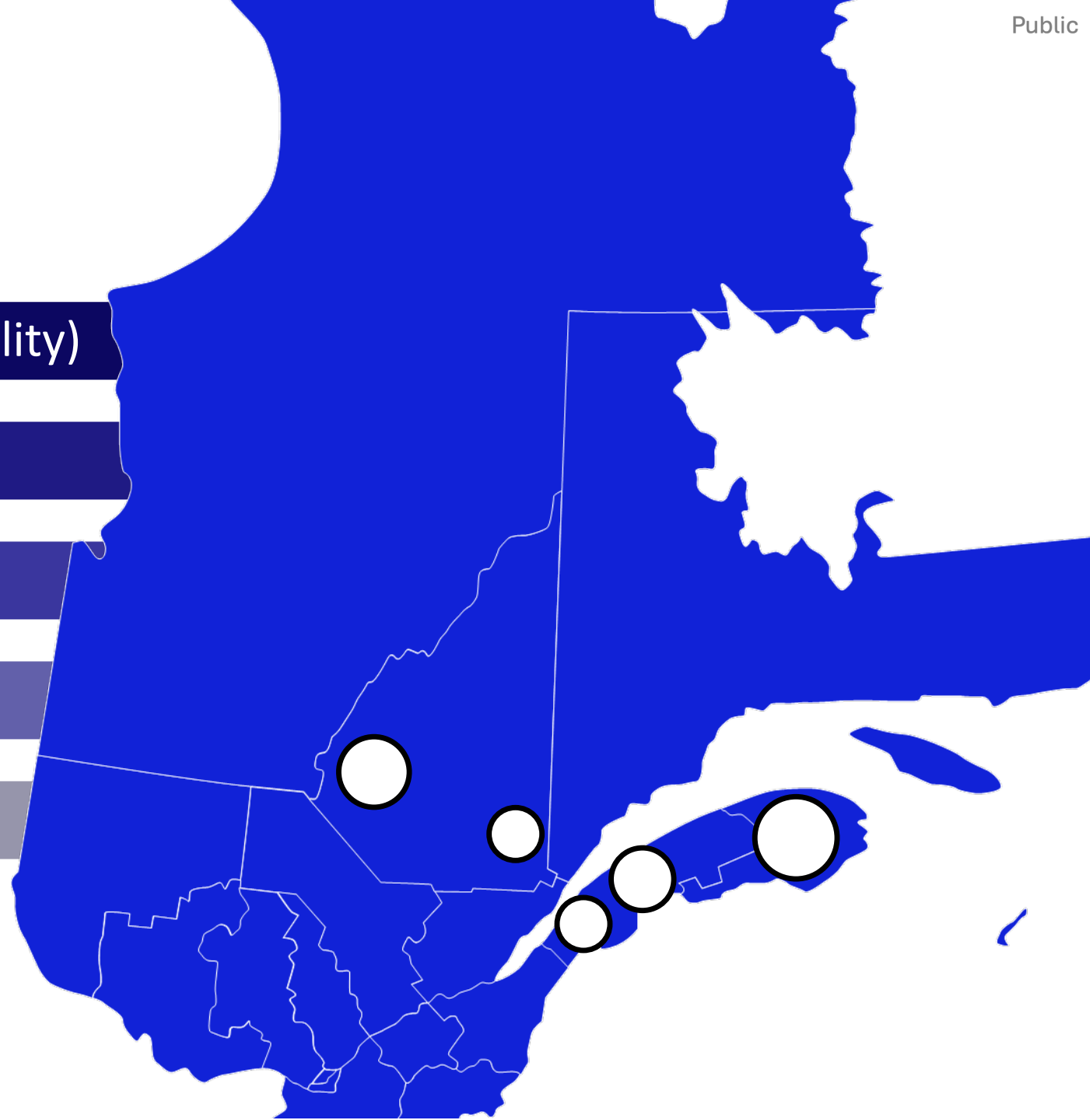
# A portfolio of options under development

Mapping of the areas announced by Hydro-Québec in recent months



# Integration challenges

- Low short circuit ratio (PLL instability)
- Voltage control issues
- Severe overvoltages
- Severe undervoltages
- Voltage unbalance



# Integration studies

## Validation angles

Protection operation

Control system capability and performance (software)

Control system capability and performance (hardware)

Equipment capability (convertisseur)

Mechanical equipment capability (machine)

Auxiliary services capability

Structure capability (tower)

## Phenomena

Undervoltages (LVRT)

Faults (Single and successive)

Low SCR operation

Overtages (OVRT)

Voltage unbalance

Frequency variations (Rocof and FRT)

Phase angle jump

Harmonic content

SCR variation

## EMT studies

Control system validation

Parameterization

Control stability

Harmonic stability

Sub synchronous phenomena

Grid code requirements

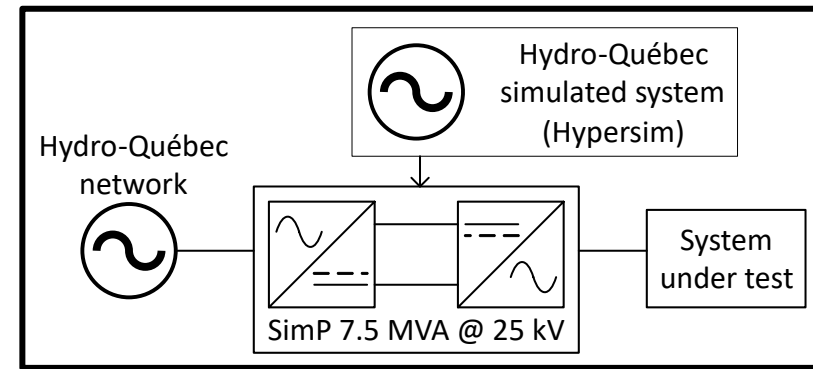
Model validation

Code upgrade validation

System events analysis and reproduction



# Benefits of PHIL testing

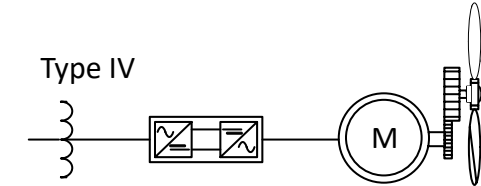
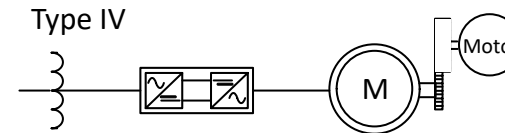
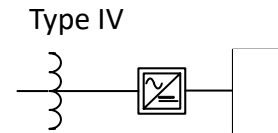


System under test

**OPTION 1**  
grid side converter + DC source  
(applicable for type IV only)

**OPTION 2**  
Full converter + machine + gearbox

**OPTION 3**  
Full turbine



Inverter protection operation, IBR protection

Yes

Yes

Yes

Control system capacity & performance (software)

Yes

Yes

Yes

Control system capacity & performance (hardware)

Yes

Yes

Yes

Equipment capacity (converter)

Yes

Yes

Yes

Equipment capacity (machine)

No

Yes

Yes

Auxiliary services capability

No

No

Yes

Structure capacity

No

No

Yes



# Thank you!

*From Utility to Developer: Simulator-Based Testing Needs Driven by  
Hydro-Québec's Emerging Wind Developer Role*