# Utility Scale Photovoltaic Systems and Land-Use in Ontario

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## BACKGROUND

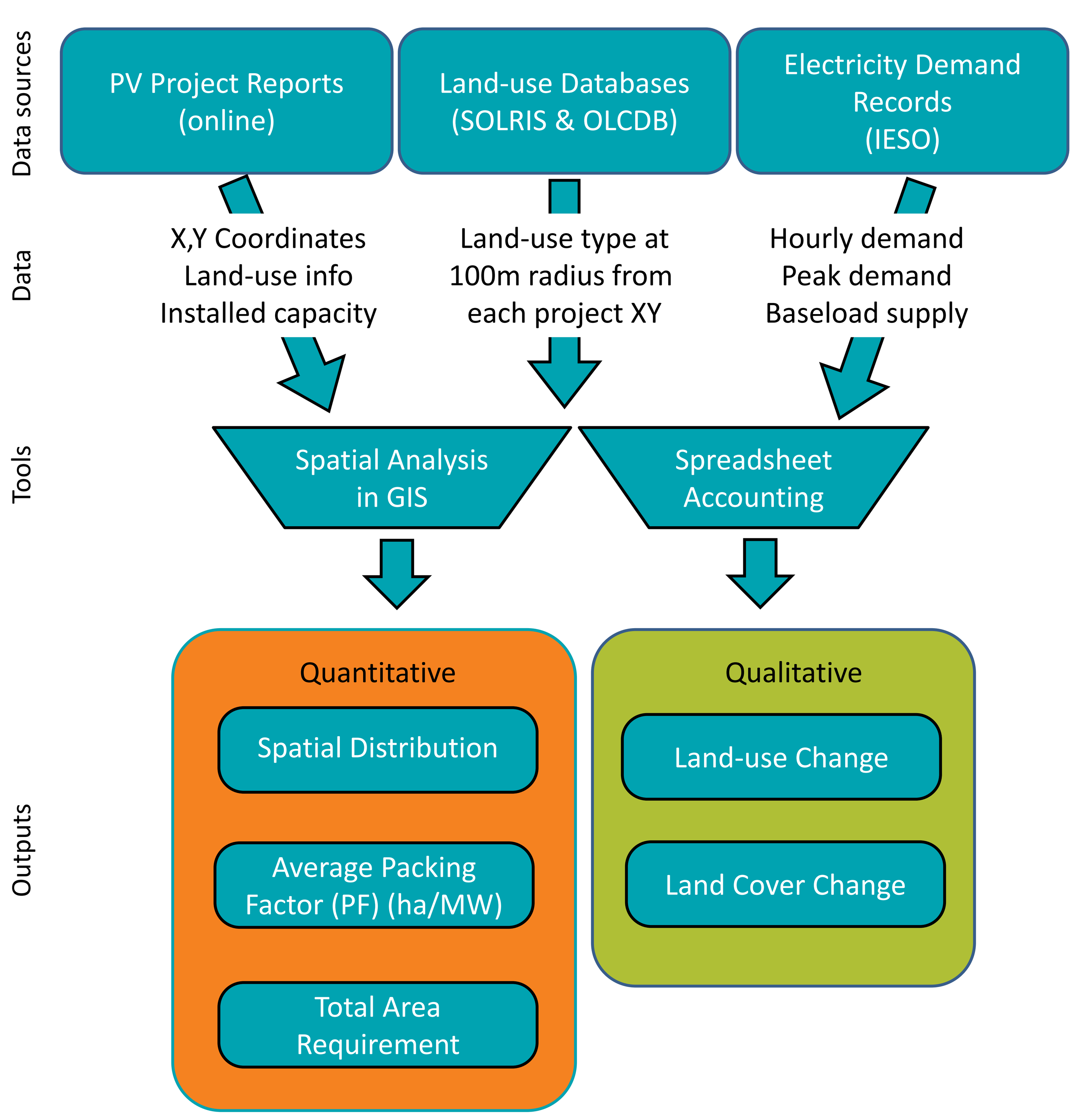
As the sun provides approximately 10,000 times the energy currently consumed in fossil fuels, solar energy is a crucial part of the solution to climate change. Ontario's Standard Offer Program and then various iterations of the Feed-In Tariff program under the Green Energy Act have spurred significant development of utility scale photovoltaic (PV) systems across the province. PV systems are locally land-intensive, bringing new opportunities as well as challenges to rural areas. Concerns have been raised about the scale of land-use change, along with ethical questions about farmland conversion to PV. Clearer understanding of the land-use issues related to PV will improve links between energy planning and land-use planning / management

## OBJECTIVES

1. Map utility-scale (i.e., >1 MW) ground-mount PV systems according to precise geographic coordinates (Figure 1)
2. Describe land-use changes in terms of the type of land-use conversion and land-cover change (Figure 2). Estimate total area of land converted, and estimate an average packing factor (PF) in terms of hectares per megawatt of installed capacity (ha/MW) (Table 1).
3. Incorporate information from (1) and (2) into numerical models to develop scenarios of future changes to land-use associated with more aggressive PV implementation (Figure 3 and Table 2)

## METHODS AND DATA

***Objectives 1 & 2***




***Objective 3 Scenarios (Figure 3 and Table 2)***

- Scenario 1: Current electricity demand profiles, nuclear provides baseload, PV meets midday peak demand.
- Scenario 2: 100% electrical vehicle fleet, nuclear provides baseload, PV meets midday peak demand.
- Scenario 3: Current electricity demand profiles, all nuclear is decommissioned and PV meets all midday electricity demands.
- Scenario 4: 100% electrical vehicle fleet, nuclear is decommissioned and PV meets all midday electricity demands.

***Description of Data:***

- Data on ground-mount and rooftop PV systems under contract retrieved from Feed-In-Tariff (FIT) reports released by the Ontario Power Authority.
- Project-specific data retrieved from construction reports posted online (e.g., http://sandringham.invenergyllc.com/).
- **238 project reports representing 1299.53 MW were retrieved**. We extracted information about technology (installed capacity, panel type, inverter type) and geography (total project area, area of panels, location, prior land use).
- **102 project reports listed XY coordinates and were greater than 1 MW in size. These are the data represented in Figure 1 and summarized in Figure 2 and Table 1.**
- Prior land-use determined through triangulation of project construction reports, overlays onto SOLRIS and OLCDB land-cover data, and verification in Google Earth.
- Total agricultural land area in Ontario derived from the 2011 Census of Agriculture

## RESULTS

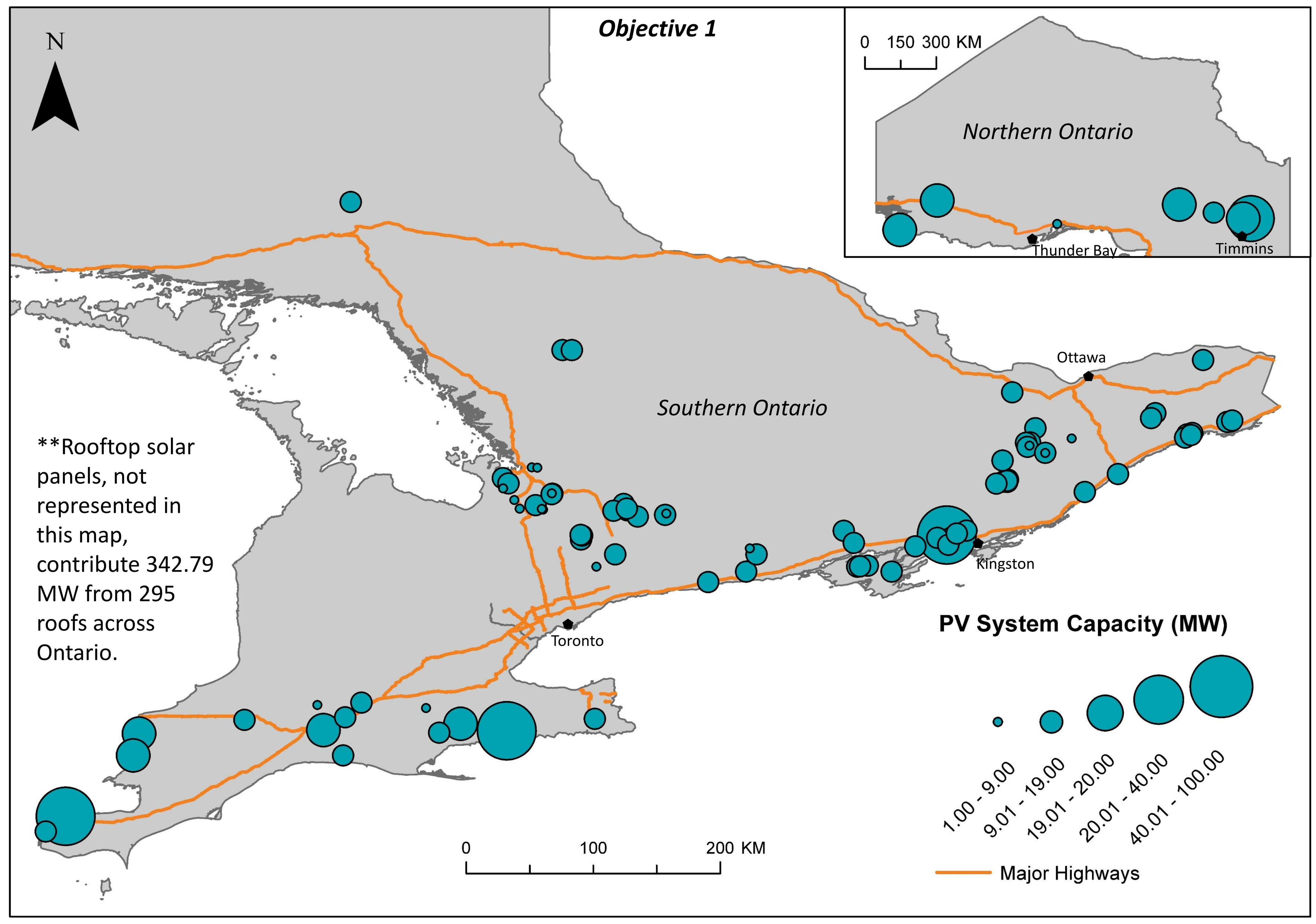



**Figure 1.** PV systems in Ontario. Only those systems for which XY coordinates could be determined are shown here. This map represents 102 systems totaling 1213.60 MW, at various stages of development.

***Objective 2***

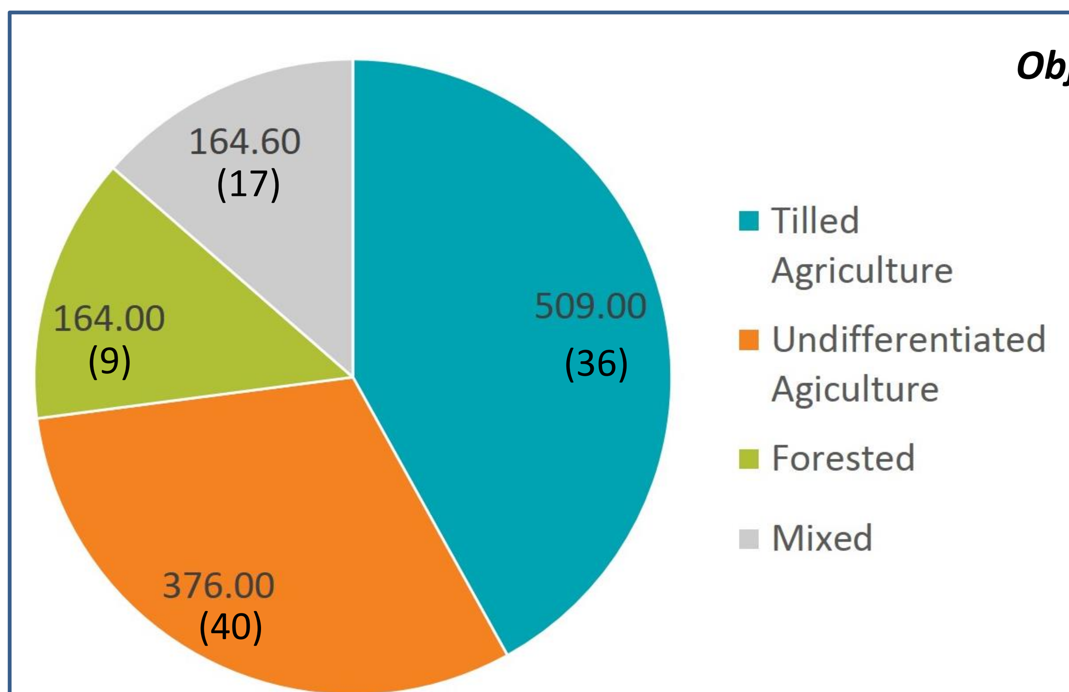



**Figure 2.** Prior land-use type for systems mapped in Fig. 1 by the number of systems and installed capacity (in brackets).

| Land Type | Total Area (Ha) | Average Packing Factor (Ha/MW) |
|---|---|---|
| Forested | 463.50 | 3.39 |
| Mixed | 794.00 | 6.24 |
| Tilled Agriculture | 1,986.86 | 5.02 |
| Undifferentiated Agriculture | 2,145.52 | 6.74 |
| All | 5,389.88 | 5.79 |

**Table 1.** Packing factors vary by prior land-use / land-cover type. On average, 5.79 ha are required for each MW of installed PV capacity. The total land requirement to date, at 5,389 ha, represents .001% of Ontario's total agricultural land.

***Objective 3***

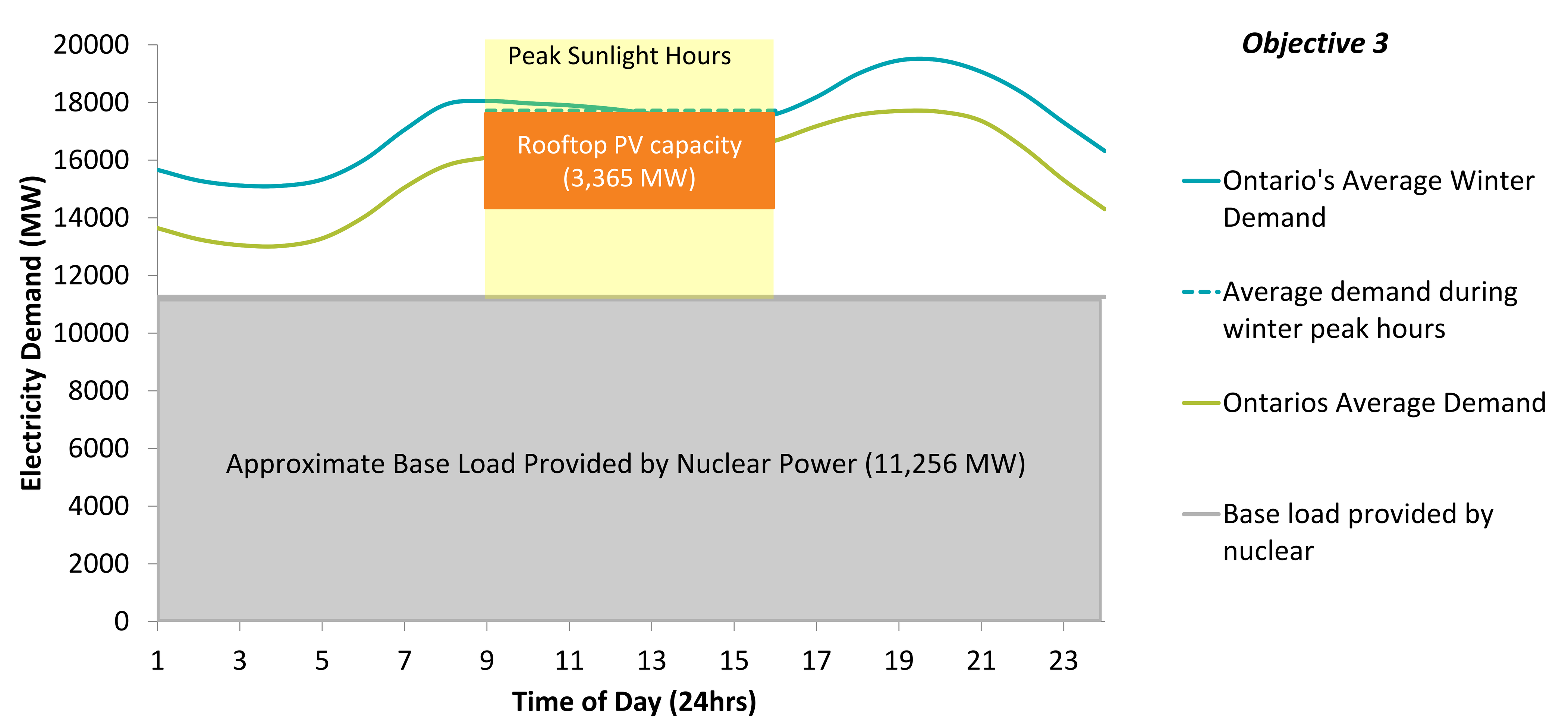



**Figure 3.** Electricity demand profiles used to estimate the quantity of land required in order to meet Ontario's peak electricity demands with utility PV systems, under four scenarios (see Table 2). In all scenarios, rooftop capacity is estimated to provide 19% of peak demands, assuming all practical rooftop segments are utilized (see Chow et al., 2016).

| Scenarios | With Nuclear Electricity | | | Without Nuclear Electricity | | |
|---|---|---|---|---|---|---|
| | Capacity (MW) | Total Land Area Required (ha) | % of Ag land | Capacity (MW) | Total Land Area Required (ha) | % of Ag land |
| **Current Peak Demand** | 3,093 | 17,911 | 0.35 | 14,349 | 83,084 | 1.62 |
| **Current Demand + all-electric vehicle fleet** | 30,031 | 173,876 | 3.39 | 41,287 | 239,049 | 4.66 |

**Table 2.** Summary of PV land requirements under the 4 scenarios described in methods, assuming a PF of 5.79 ha/MW.

## DISCUSSION AND CONCLUSION

Our results indicate some clustering of PV projects, particularly in the Kingston and Barrie regions. Although a number of factors might explain this, including spatial variations in grid capacity and land prices, further research is needed to identify and explain statistically significant clusters. In this study we identified an average packing factor (PF) of 5.79 ha/MW. This is slightly larger than the average PF found in other parts of the world, including the southwestern US (3.32 ha/MW in (Hernandez (2015); Sullivan et al (2015))) and India (2.02 ha/MW, in (Mitavachan et al (2012))). Reasons why packing factors in Ontario are higher are unclear, but are likely related to landscape complexity relative to many of the other regions under study (e.g., California deserts). Future research should identify reasons why packing factor varies across geography and, in particular, why PV systems developed on what used to be forested land seem to have lower packing factors. Even under very aggressive PV development scenarios (e.g., scenario 4 above), land requirements are manageable at a provincial scale but could still be considered intrusive at localized scales. It is more likely that PV will be part of a more diverse fuel mix, especially as storage technology becomes a viable option, and will not be the only solution toward meeting peak demands in Ontario. Overall, the methods and findings in this study could be applied to improve integrated land-use and energy planning at provincial and regional scales.

**References:**
Hernandez. R., Hoffacker. M., Field. C. (2015) Efficient use of land to meet sustainable energy needs. Nature Climate Change 5 353-358.
Mitavachan. M., Srinivasan. J. (2012) Is land really a constraint for the utilization of solar energy in India? Current Science, 2 163-168
Sullivan, R., Kirchler, L., McCoy, C., McCarty, J., Beckman, K., Richmond, P.(2014) Visual impacts of utility-scale solar energy facilities on southwestern desert landscapes.