Social Justice on Residential Solar in Seattle

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Background: Energy divide

- This transition to the new energy system could lead to an emerging electrical divide like the digital divide of the late 20th century.

- Committed leadership to implement a new policy in regard to the transition is required to avoid the uneven distribution of the service.

Issues: Residential solar in Seattle

- Residential solar installations have rapidly increased with advancement of clean energy policies.

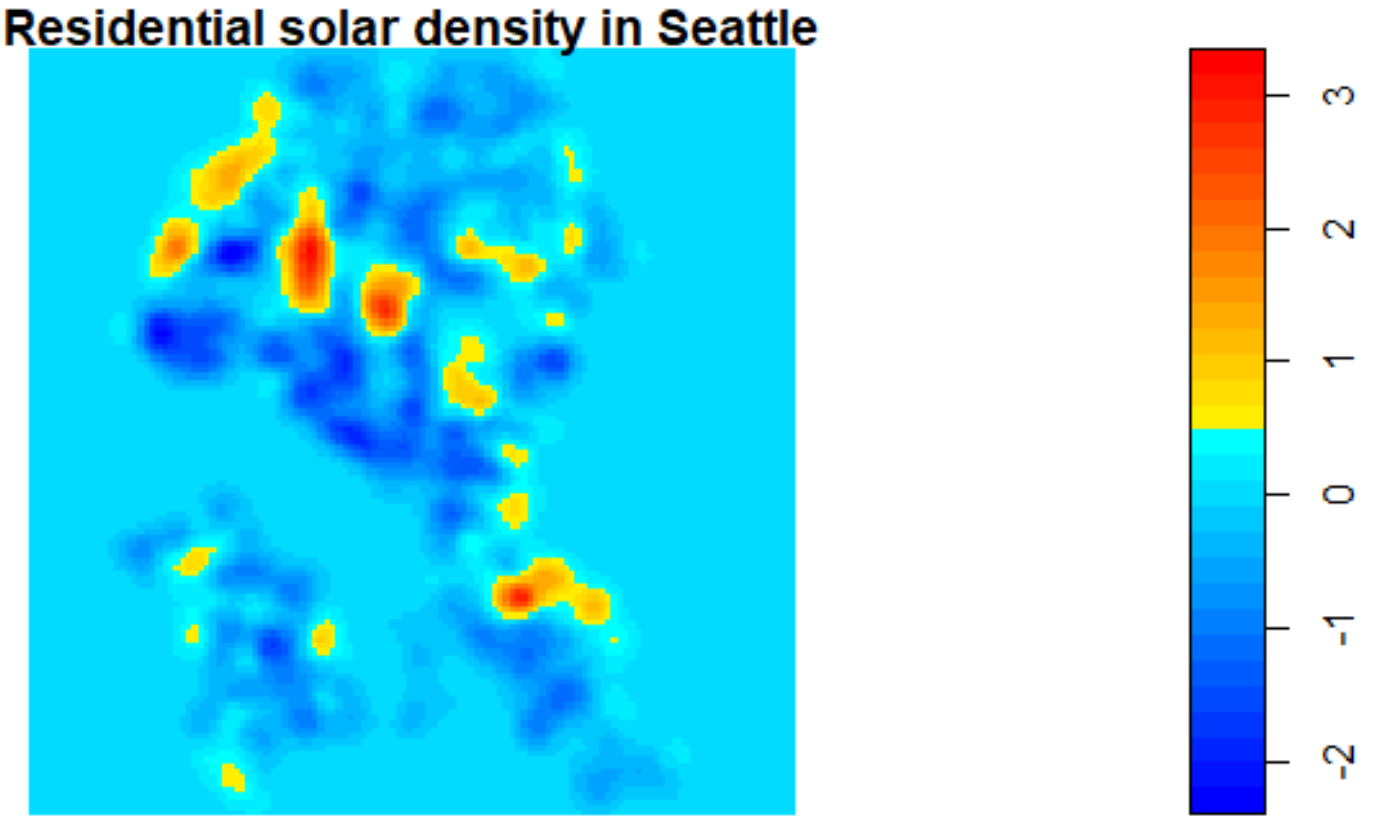
- To investigate the impact of such policies on the social equity, two questions have emerged:

  (1) Were there certain communities left out from incentive opportunities?

  (2) Do those current policies help the social equity?

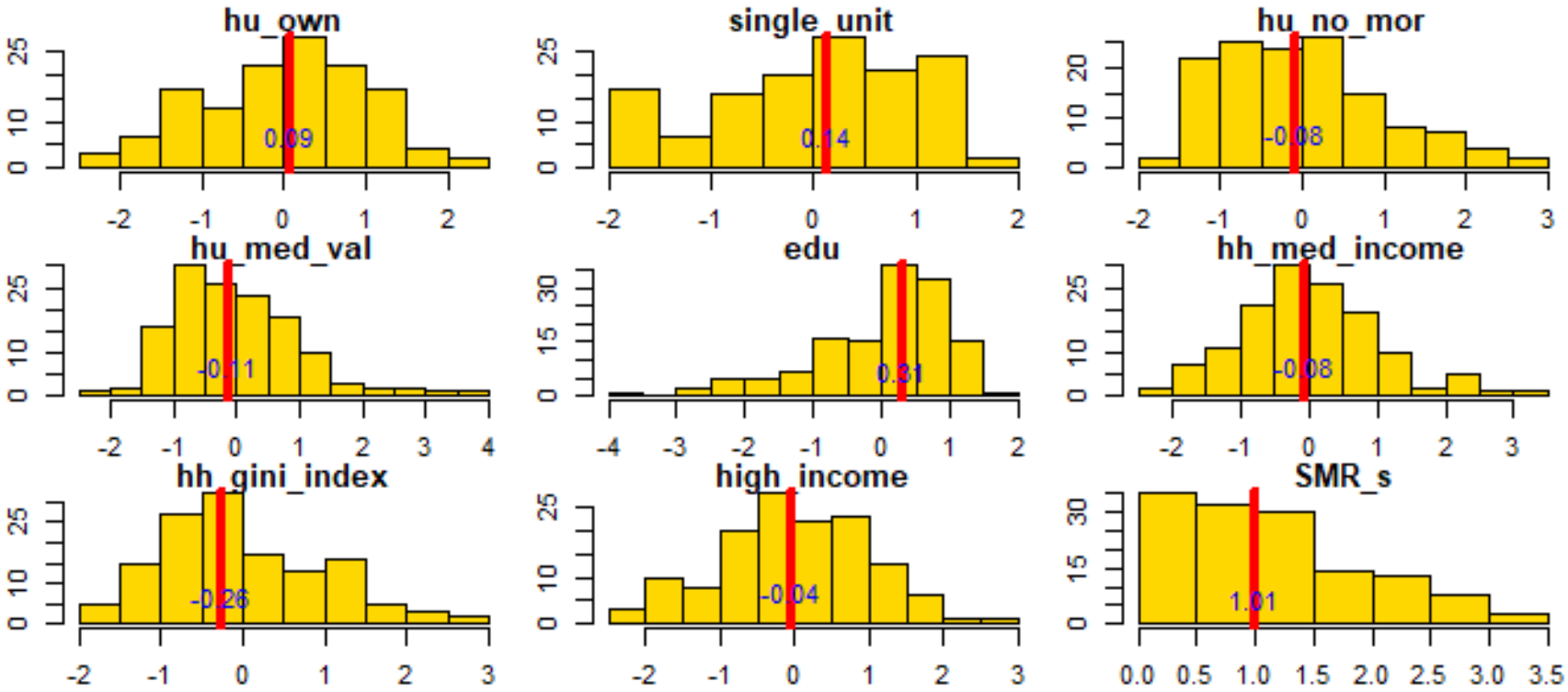
Solar distribution in Seattle

- Clustering pattern on distribution



Solar density normalized by the number of residential house units.

Socio-economic characteristics

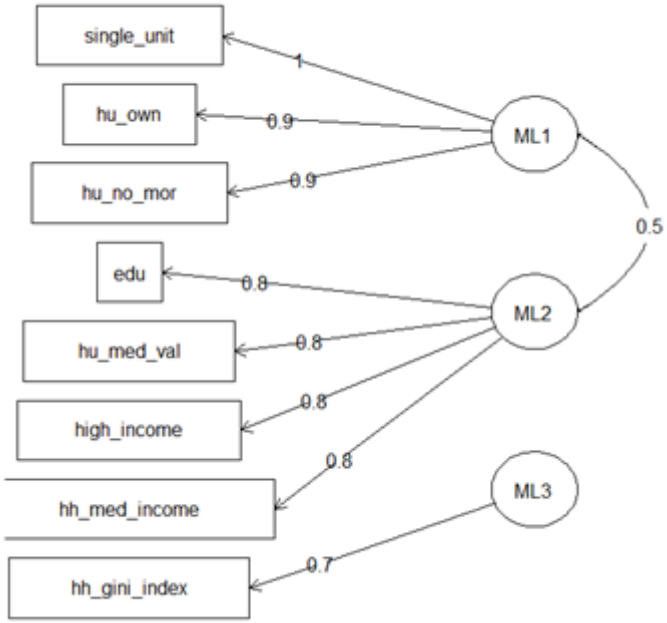


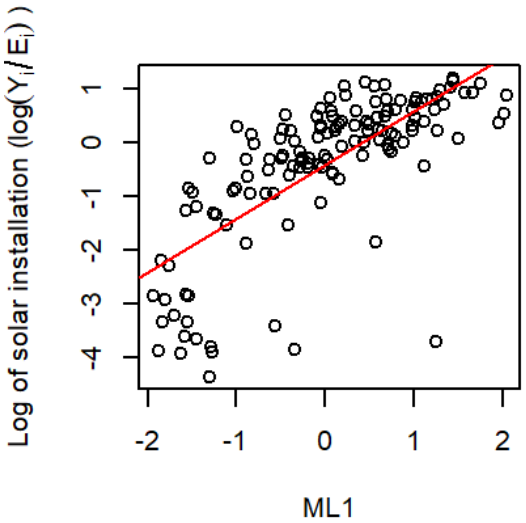
- **hu_own**: owner-occupied housing units
- **single_unit**: single family housings
- **hu_no_mor**: owner-occupied housing units without a mortgage
- **hu_med_val**: median value of owner-occupied housing units
- **edu**: population above high school degree
- **hh_med_income**: household median income
- **hh_gini_index**: household GINI Index of income inequality
- **high_income**: high income households
- **SMR_s**: the ratio of solar installation to the expected number of installations in regard to the total number of the residential housing units of the given census track (2003 – 2018)

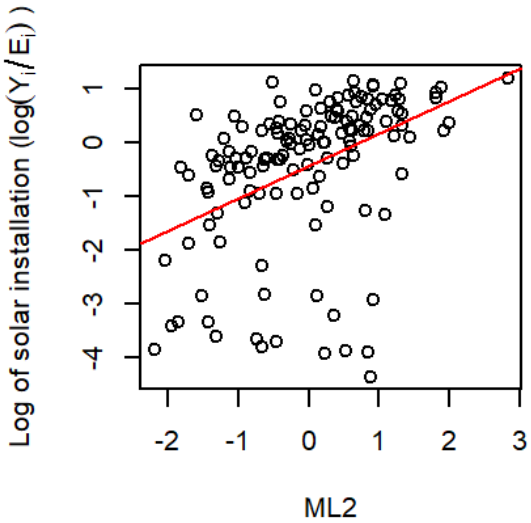
Factor analysis

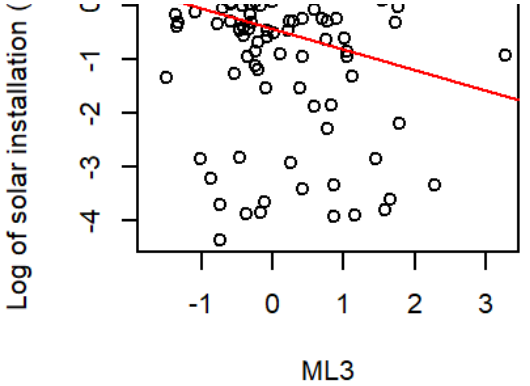
- Socio-economic characteristics into 3 factors.

In consideration of avoiding multicollinearity, FA identifies ML1 (housing unit structure and housing tenure), ML2 (economic status), and ML3 (inequality index).









Intrinsic Conditional Auto-Regressive

- Spatial autocorrelation model (INLA)

$$
\begin{aligned}
Y_i|\beta_0,\beta_1,\beta_2,S_i,\epsilon_i &\sim_{ind} \text{Poisson}(E_i\,\mathrm{e}^{\beta_0+\beta_1 I_{1i}+\beta_2 I_{2i}}\,\mathrm{e}^{S_i+\epsilon_i}),\\
\epsilon_i|\sigma_\epsilon^2 &\sim_{iid} \text{N}(0,\sigma_\epsilon^2),\\
S_1,\ldots,S_n|\sigma_s^2 &\sim \quad \text{ICAR}(\sigma_s^2).
\end{aligned}
$$

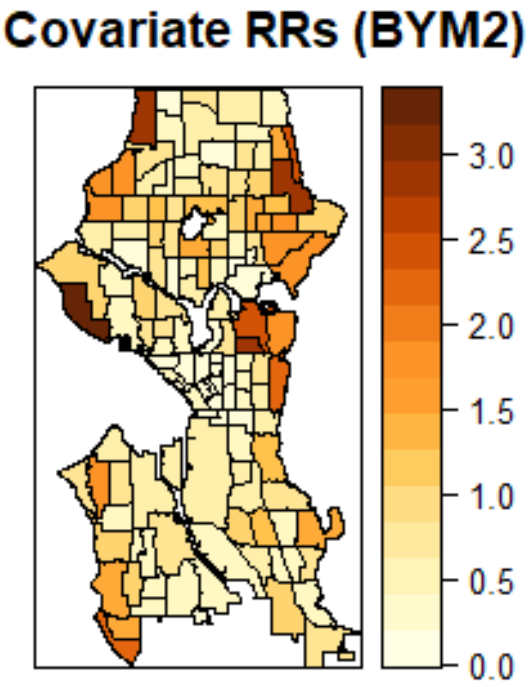
The large variance is due to the spatial dependency with ϕ of 0.96 (*ϕ is between 0 and 1, closer to 1 means higher spatial dependency).*

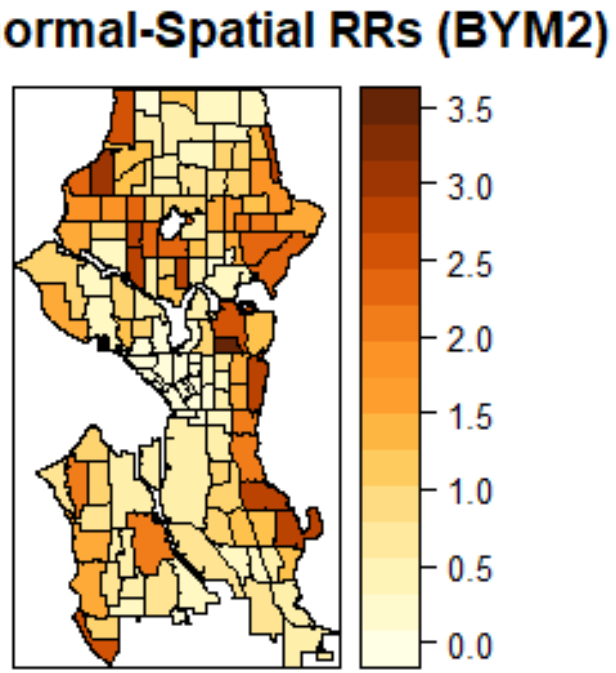
	mean	0.025quant	0.5quant	0.975quant
(Intercept)	-0.3012	-0.3604	-0.3008	-0.2437
I(ML1)	0.5551	0.4121	0.5549	0.6985
I(ML2)	0.182	0.04388	0.1816	0.3222
Total SD	0.6523	0.7902	0.6576	0.5488
Phi for ID	0.959	0.828	0.9749	0.9986

ICAR model mapping

- The two factors well explain the solar density.

  The map in the left is a plot of the two factors while the map in the right is a plot of solar installation.

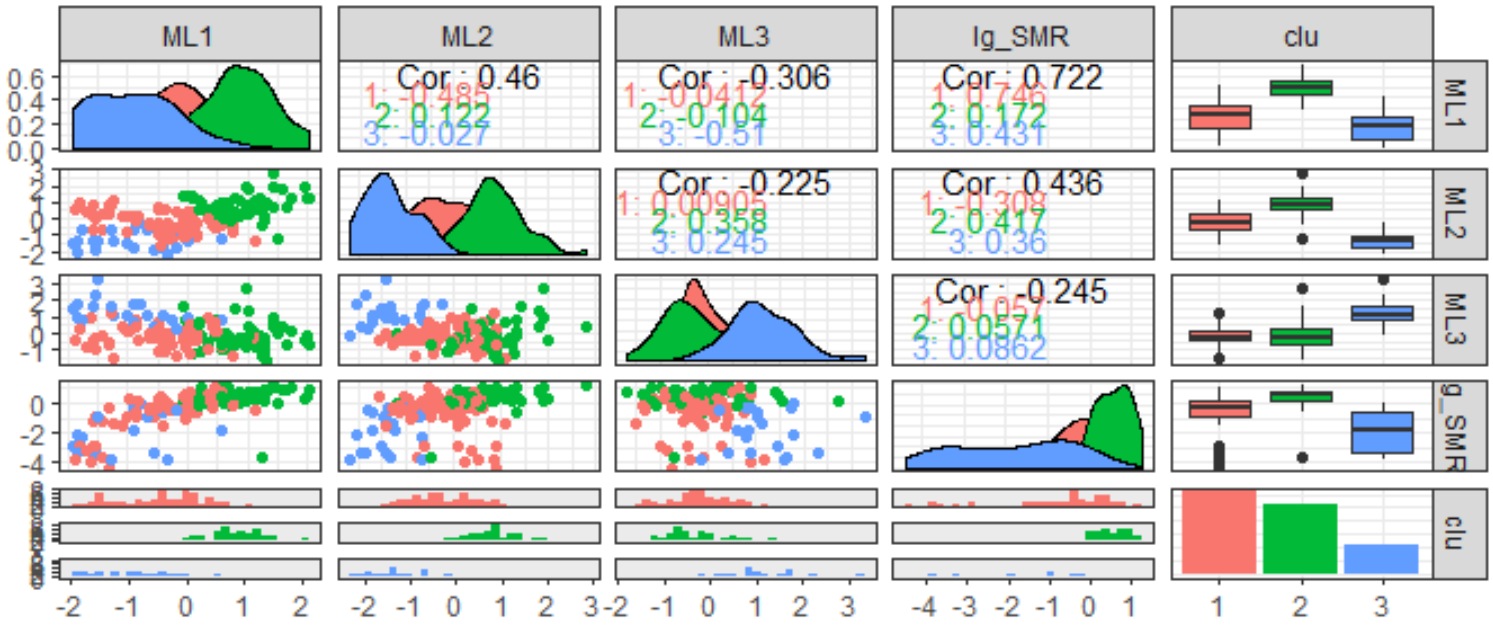




K-means clustering

- 3 clusters in terms of 3 factors.

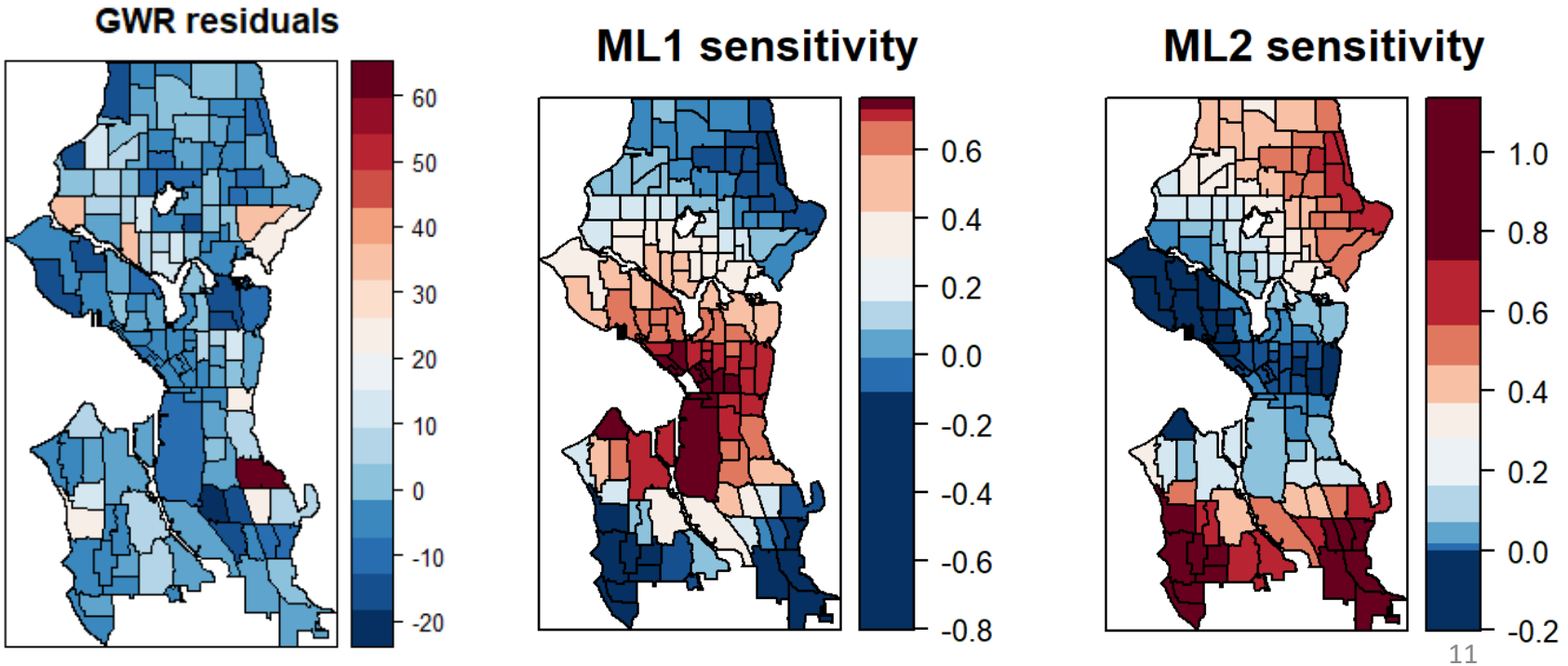
  K-means cluster analysis indicates groups of census tracks with the similar characteristics. Three groups are categorized showing the clustering pattern with respect to housing stability (tenure and structure) and economic status.



Geographically weighted regression

GWR model considers spatial dependence in a local level by changing the coefficient values of covariates. Housing stability impacts more on the central Seattle while North and South Seattle are more sensitive to the economic status for the residential solar.

$$Y(s) = E(s)\mathrm{e}^{(\beta_0+\beta_1(s)X_1(s)+\beta_2(s)X_2(s)+\epsilon(s))}$$

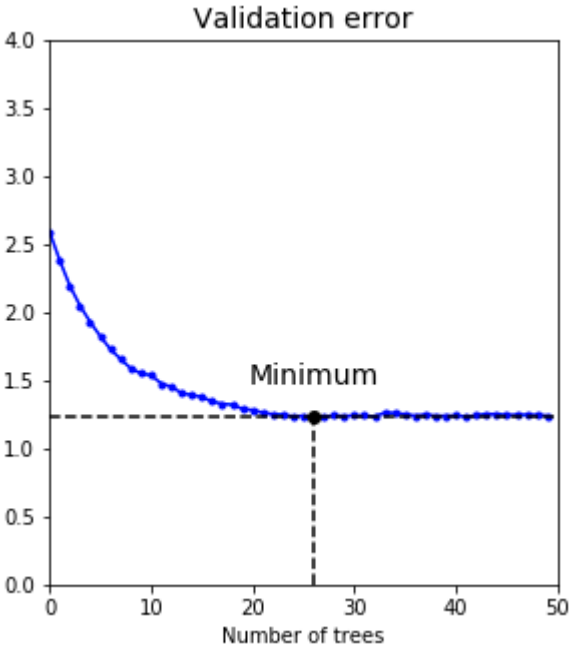


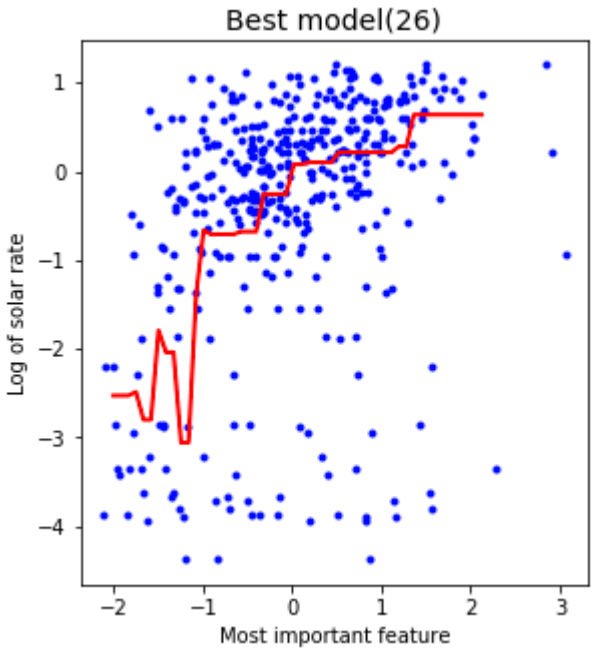
Prediction (gradient boosted random forest)

- Identifying the vulnerable communities by machine learning prediction.

- Max depth=2
- Learning rate=0.1
- Estimators=50
- Train to test=0.8

26 tree estimators predict the best and the most important feature in this model is ML1.





Why care?

- Vulnerability: centralized energy production may contribute to vulnerability. The more dependent to a sole energy production, the more vulnerable a system would be facing interruptions.

- Resilience: climate change and its impact on urban systems on resilience abilities to ensure sustainability related dimensions. Availability for sustainable dimension and preparation for resilience ability are the most critical.

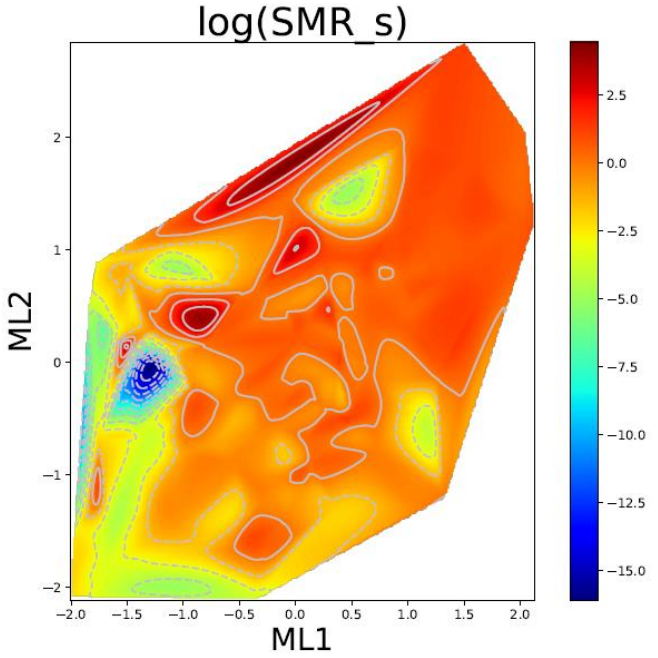
How to address

- Spatial diversification: the need of the polycentric governance as it is critically related to socio-economic actors.

- Decentralization: decentralized energy network will enhance the energy accessibility.

Conclusion - application

- Residential solar installations are influenced by
  (1) mostly housing stability (single family house unit proportion and housing tenure)
  (2) moderately economic status (income level and house value)



- The results shows there are certain communities left out from using the renewable energy technology due to the resources (i.e., housing and finance), thus policy makers refer to this study to identify the communities.

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