SURVIVAL ANALYSIS OF BEHIND THE METER GENERATION PROJECTS

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VERDANT

BACKGROUND

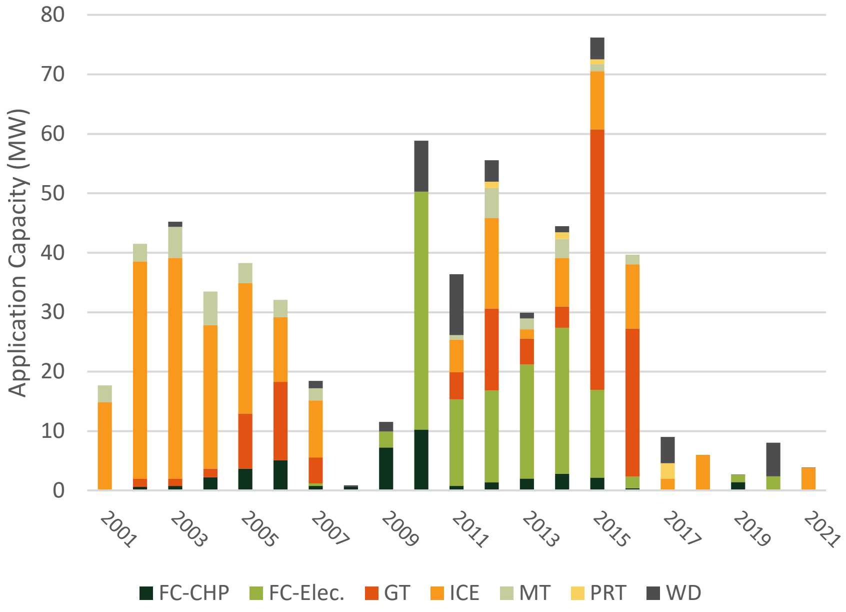
Self-Generation Incentive Program (SGIP)

» SGIP projects were estimated to provide 4,081 GWh of on-site electricity in 2018 and 2019 (combined)

» Provides incentives for generation technologies:

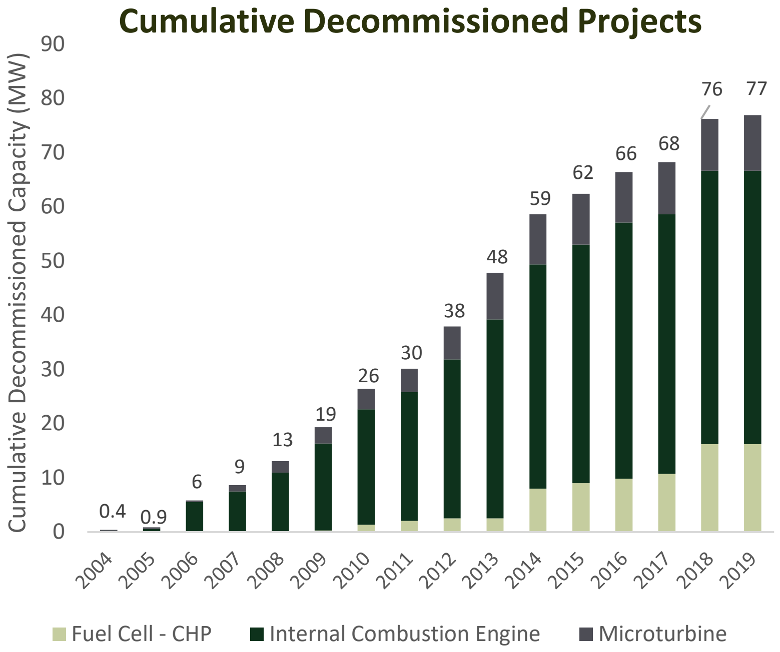
- Fuel Cells,
- Gas turbines,
- Internal Combustion Engines,
- Micro-Turbines,
- Pressure Reduction Turbine
- Wind Turbines

» Program focus has shifted away from generation technologies



BACKGROUND

Decommissioning of Projects



Current Scenario

- Existing projects continue to age and become decommissioned
- New SGIP capacity additions and applications have decreased greatly since 2016.

Research Questions

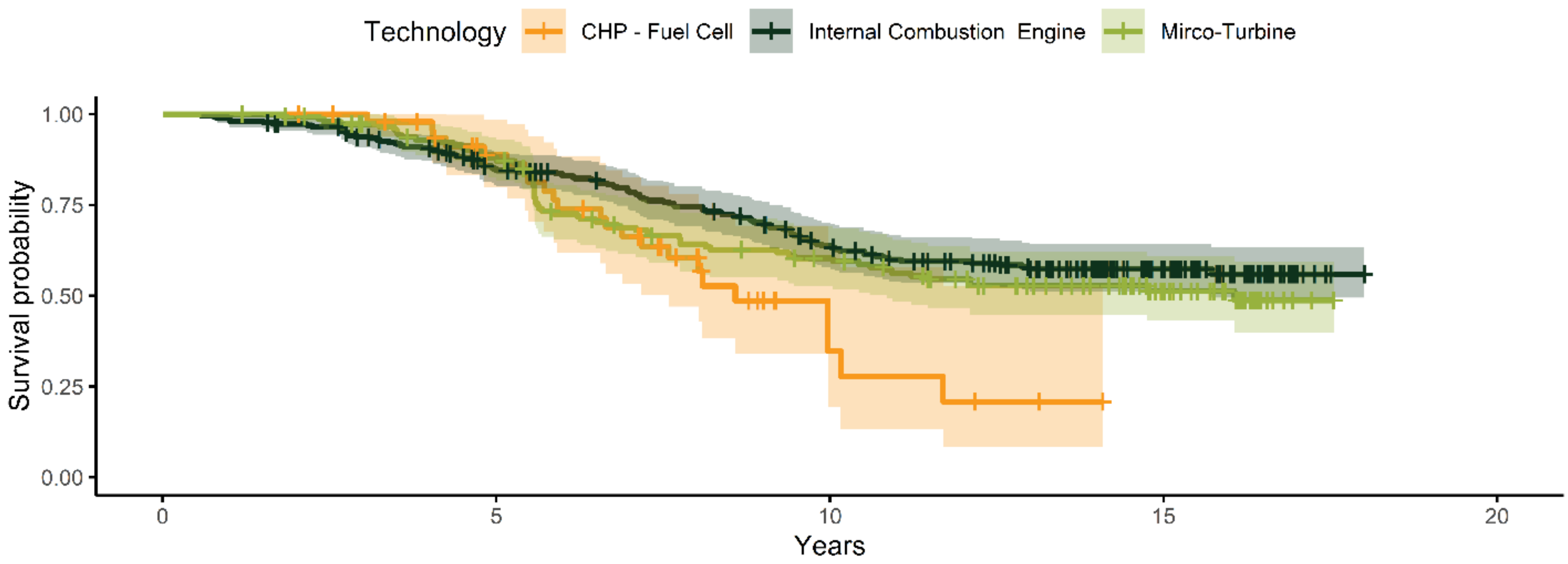
- How much capacity of existing projects can be expected to remain operational in future years?
- Are there specific project characteristics that increase the likelihood of project decommissioning?
  - Technology
  - Fuel Type
  - Project Size (Capacity)
  - O&M Costs
  - Project Vintage

SURVIVAL ANALYSIS METHODS

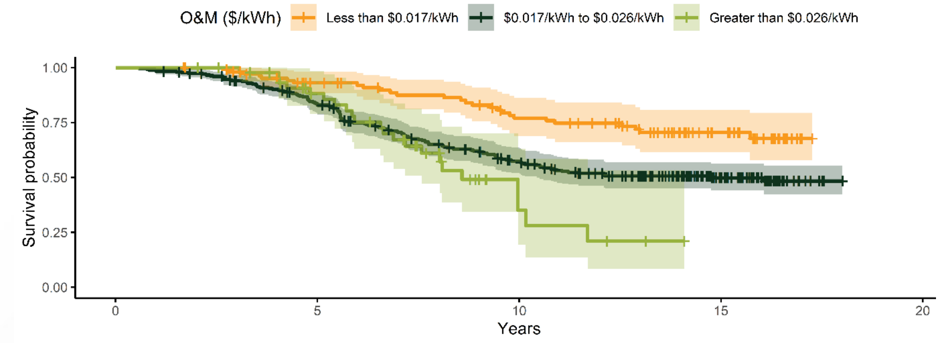
Kaplan-Meier (KM)	• Step function of decreasing survival probabilities over time. • Presents the actual survival curve of a population • Does ***not*** allow for multivariate analysis • Pairwise-Log Rank Test to check for significant differences between groups
Cox Proportional Hazard	• Estimates relative risks of decommissioning between two levels of project characteristics (Hazard Ratio) • Logistic regression-based model that allows for multivariate modeling • Does not allow for time varying hazards
Parametric Modeling	• Regression based approach that allows for multiple covariates • Allows for both time constant and time varying hazard rates • Assumes a defined parametric distribution • Is used for predicting decommissioning in this study

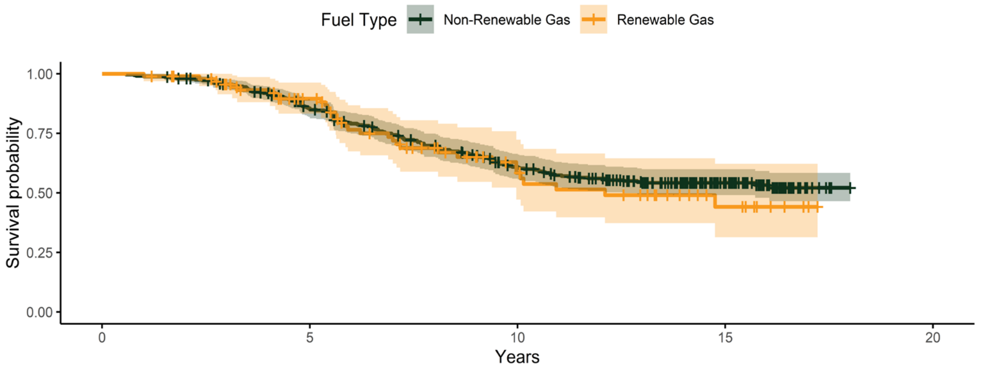
KAPLAN-MEIER SURVIVAL CURVES

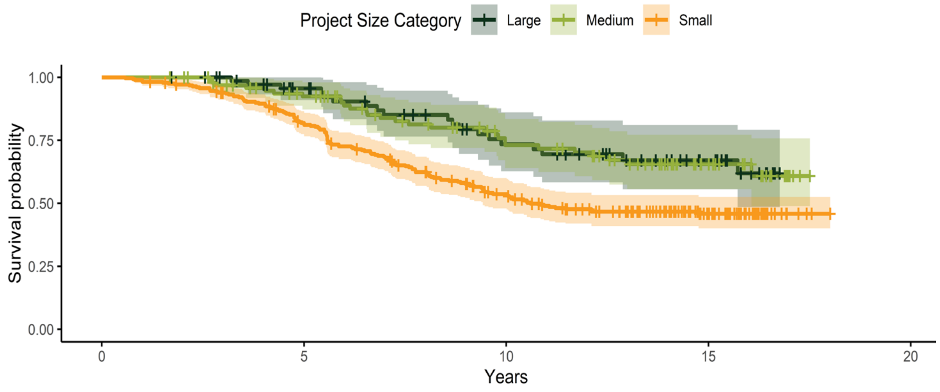
TECHNOLOGY KM SURVIVAL CURVES

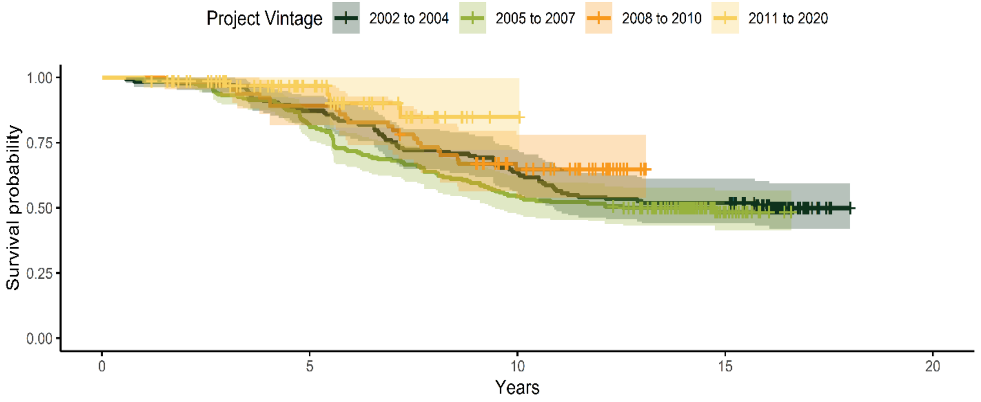


KM SURVIVAL CURVES









PROPORTIONAL HAZARDS

COX PROPORTIONAL HAZARD

Modeling

- **KM** is great, but **does not allow for a direct comparison of hazards** within segments
- Model Development
  - Multivariate model that includes; O&M costs, Size Bin, Project Vintage and Fuel Type
  - **Technology groups are not included** due to high correlation with other project characteristics
  - **Large and medium** sized projects are **grouped together.** KM curves show that these groups have virtually the same
  - **O&M costs are transformed** from $/kWh to $/100/kWh

- Caveat: Cox Proportional Hazards do not allow for time varying hazards. KM curves show nonlinear survival curves and time varying hazard rates

COX PROPORTIONAL HAZARD RATIOS

Category	Parameter	Coeff.	Hazard Ratio -exp(Coeff)	p-value	Statistically Significant?
O&M Cost	O&M Cost (Cent/kWh)	0.331	**1.393**	0.000	Yes
Capacity	Capacity Size - Small	0.444	**1.560**	0.0126	Yes
Project Vintage	Vintage - 2005 to 2007	0.071	**1.073**	0.665	No
	Vintage - 2008 to 2010	-0.436	**0.646**	0.0883	No
	Vintage - 2011 to 2020	-1.239	**0.290**	0.0124	Yes
Fuel Type	Non-Renewable	0.198	**1.219**	0.3149	No

Interpretation

Parameter	The probability of decommissioning…
Normalized O&M Cost (Cent/kWh)	***Increases by 39%*** for every ***$0.01 increase*** in O&M $/kWh
Capacity Size - Small	is ***56% higher*** for small sized capacity projects
Project Vintage - 2011 to 2020	is ***71%*** lower for projects installed between 2011 to 2020 compared to projects installed from 2002 to 2004

ESTIMATED AVAILABLE CAPACITY FOR FUTURE YEARS

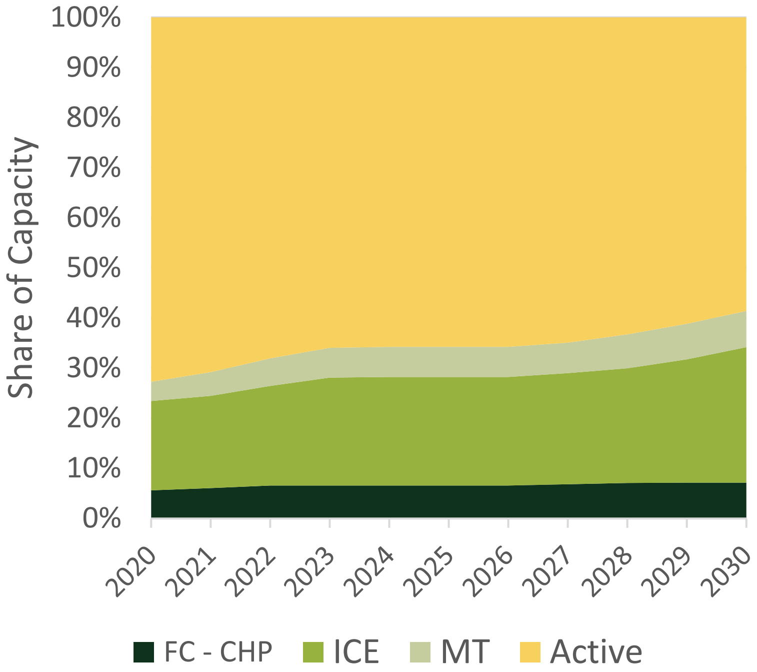
PARAMETRIC MODELING

Forecast Model

- Objective: **Estimate** available FC-CHP, ICE and MT **project count and capacity** in 2023, 2025 and 2030
- We assume a **Weibull distribution** for our parametric survival model.
  - Allows for time varying hazards: allowing hazards to increase, remain constant and then increase again with time *t*.
- We use the **same model specification used in the Cox modeling,** which includes normalized O&M costs, capacity size bin, project vintage bins and fuel types

PROJECT CAPACITY (MW)

Forecasted Remaining Capacity



Tech.	Total MWs prior to 2020	Active MWs prior to 2020	Forecasted MWs of remaining capacity		
			2023	2025	2030
FC- CHP	42	27	23	23	22
ICE	205	155	144	144	128
MT	36	26	18	17	14
Total	**284**	**208**	**185**	**184**	**164**

We estimate that by 2030 an **additional 44 MW** of SGIP capacity **will be decommissioned.**

FINDINGS

FINDINGS

1. **The longevity of generation projects** appears to be **heavily influenced by** their **upkeep and maintenance (O&M) costs.**
2. **Fuel types have no statistically significant influence on survival**, suggesting that the fuel source and relative fuel price differences do not play a significant role in decommissioning decisions. THIS MAY NOT HOLD OUTSIDE OF CALIFORNIA
3. **Easy access to maintenance knowledge and skills may be important in decommissioning decisions.** The combined O&M and fuel type results may point to the importance of the need to undertake maintenance to continue technology operation instead of strictly cost considerations as a primary determinant of decommissioning.

FINDINGS
Continued

4. **Smaller ICE, MT, and FC-CHP projects have a higher probability of decommissioning** at a given time t. While the upfront cost of the system and the share of load the generation system provides was not included in this analysis, larger system may represent a larger investment for host customers, who then have a bigger interest in keeping their system online and operational.

5. We estimate that and additional **44 MW** of capacity will **be decommissioned by 2030,** however, **the majority of capacity will still be available.**
   - Remaining Capacity estimates:
     - **185 MW** in **2023**
     - **184 MW** in **2025**
     - **164 MW** in **2030**

THANK YOU

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