Modeling the 1-Step and 2-Step Dispatch Approaches to Account for GHG Emissions from EIM Transfers to Serve CAISO Load

PREPARED BY:

Judy Chang
Johannes Pfeifenberger
Kai Van Horn
Onur Aydin
Mariko Geronimo Aydin

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THE Brattle GROUP

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Executive Summary of Main Takeaways

The Brattle Team was asked to evaluate the potential impact of the "1-Step" versus the "2-Step" approaches on greenhouse gas emissions for the region.

- Conducted annual hourly production cost simulations of WECC, focusing on the EIM region
- Simulated three cases:
  - 1-Step Approach, 2-Step Approach, and all BAs manage RT imbalance internally (without EIM)

***Dispatch* impacts of 1-Step Approach vs. 2-Step Approach:**

- *EIM dispatch shows an overall decrease in coal generation output and increase in renewable generation output relative to all BAs managing own RT imbalance*
- *2-Step Approach reduces secondary dispatch and resource backfilling* and thereby captures the incremental dispatch of mostly gas generation to support CAISO load in EIM
- With the 1-step Approach, EIM transfers to CAISO load are attributed to hydroelectric EIM participating resources, which displaces gas generation serving CAISO load but increases external fossil generation

***Greenhouse Gas Emissions* impacts of 1-Step Approach vs. 2-Step Approach:**

- EIM reduces emissions in the EIM region due to displacement of coal with avoided renewable generation curtailments
- The *2-Step Approach results in modest overall atmospheric emissions reduction from the EIM region compared to the 1-Step Approach*, and more appropriately captures emissions attributable to CAISO and non-CAISO loads
- 1-Step Approach under-allocates emissions to support CAISO load (and over-allocates emissions to support non-CAISO load) due to secondary dispatch and resource backfilling

Summary of Model Assumptions

EIM GHG Modeling Approach

Starting model: Baseline schedules utilize results from an hourly nodal simulation of WECC for 2020[1]

- Starting point: Commitment and dispatch of all units outside of EIM are set at day-ahead values from the WECC simulation for 2020
- Commitment of steam turbines and combined cycle units within EIM is set at day-ahead values, with only combustion turbines and other fast-start units available for starting (incremental commitment) during EIM

The "EIM" simulation

- EIM region based on participants as of January 2017 (CAISO, PAC, PSEI, NVE, and AZPS)
- Used day-ahead import/export schedules as baseline transfers between BAs
- Limited transfers across EIM participants based on current limits (provided by CAISO)
- Lifted transmission-related trading hurdles within the EIM footprint
- Added Real-Time uncertainty to load and renewable schedules in EIM region (more details later)

Simulated existing 1-Step, proposed 2-Step dispatch, and No EIM

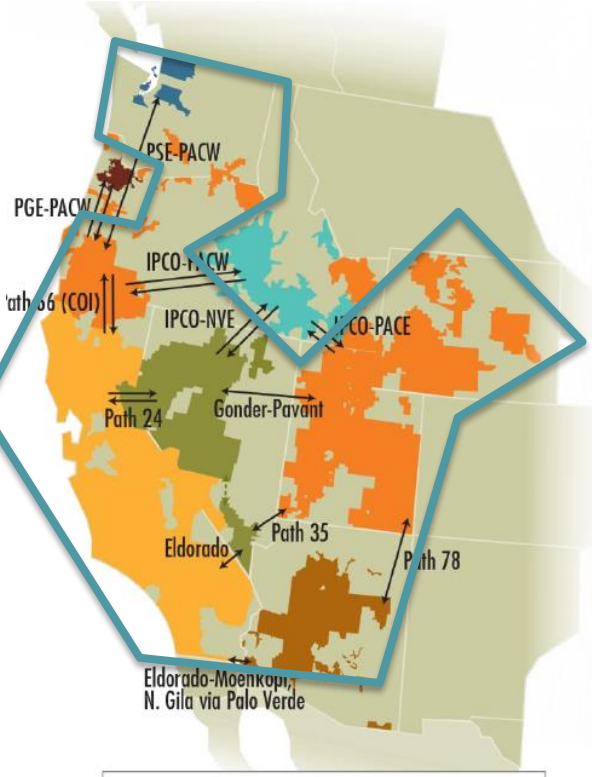
- Applied unit-specific GHG tracking (set at max emissions rate of units × GHG price)
- Limited transfers to serve CAISO load from individual units in Step-2 based on results from Step 1 (imported MWh ≤ $P_{max} - P_{step1}$)
- No RT transfers allowed between EIM BAs in the No EIM case (RT imbalance met internally)

[1]The starting point for the model was the "2020 current practices case" in our stakeholder-vetted market simulations for SB350.

Summary of Model Assumptions

EIM Footprint and Transfer Limits

"EIM region" set based on participants as of January 2017



Path	Estimated Max Capacity (MW)*
Path 24 *(west to east)*	100
Path 24 *(east to west)*	35-90
Eldorado	1,500
Path 35 *(west to east)*	580
Path 35 *(east to west)*	538
Gonder-Pavant	130
Path 66 *(ISO to PACW)*	331
Path 66 *(PACW to ISO)*	432
Path 66 *(ISO to PGE)*	627
Path 66 *(PGE to ISO)*	296
PSE to PACW	300
PGE to PACW	306
PACW to PGE	276
IPCO to PACW	1,587
PACW to IPCO	510
IPCO to NVE	478
NVE to IPCO	262
IPCO to PACE	1,000
PACE to IPCO	2,557
Eldorado, Moenkopi, N. Gila, Palo Verde	2,500
Path 78	600

*Current as of May 2016

Hurdle-free EIM transfers

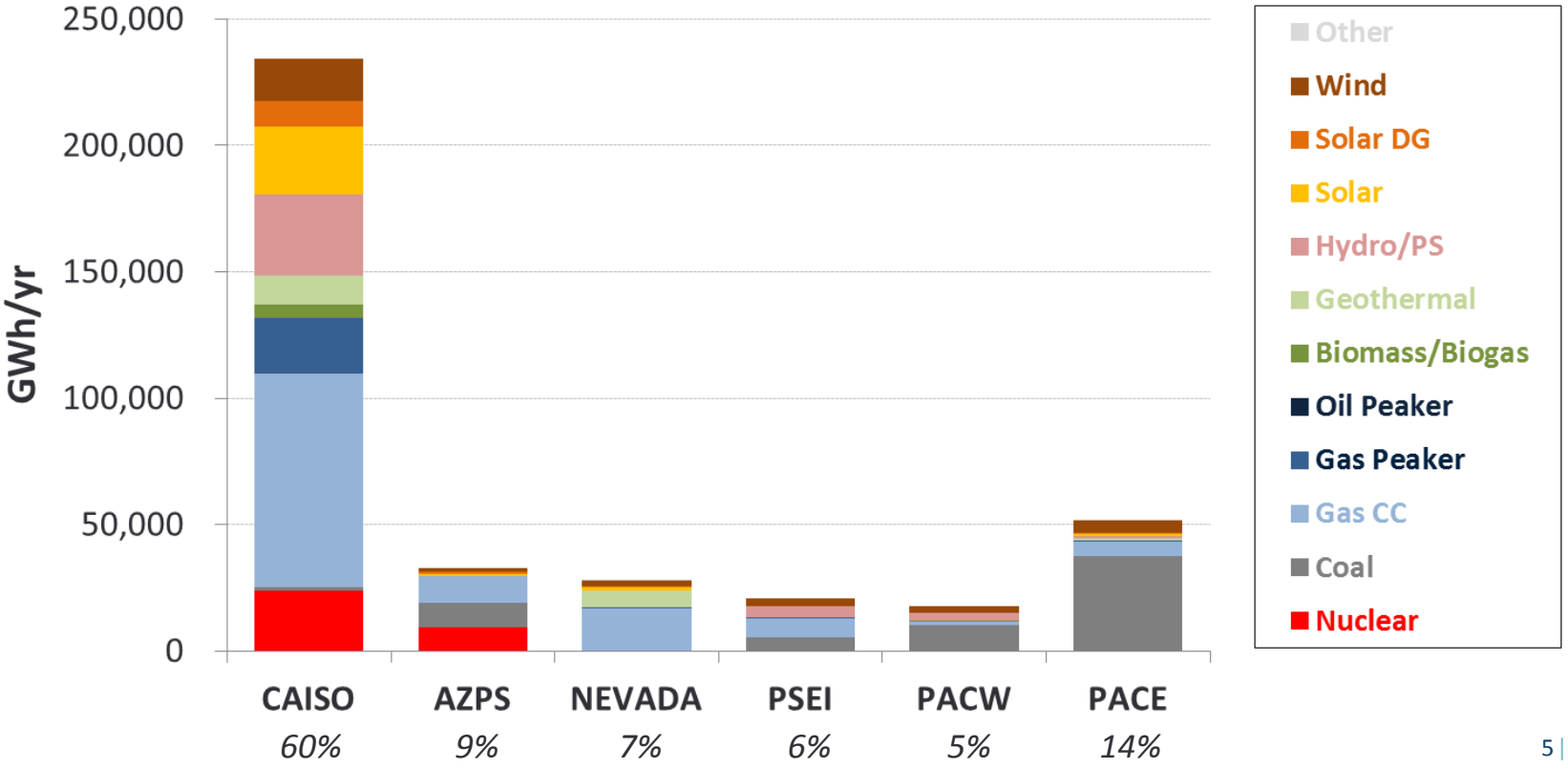
(limited to EIM transfer capabilities provided by CAISO)

Generation Mix of EIM Participants

CAISO accounts for ~2/3 of the simulated 2020 generation output in the EIM footprint

- CAISO's generation output is about 50% gas and 50% nuclear + renewables
- Other EIM entities' generation output is about 40% coal, 30% gas, and 30% nuclear + renewables

Simulated 2020 Generation Output (GWh) by EIM Area



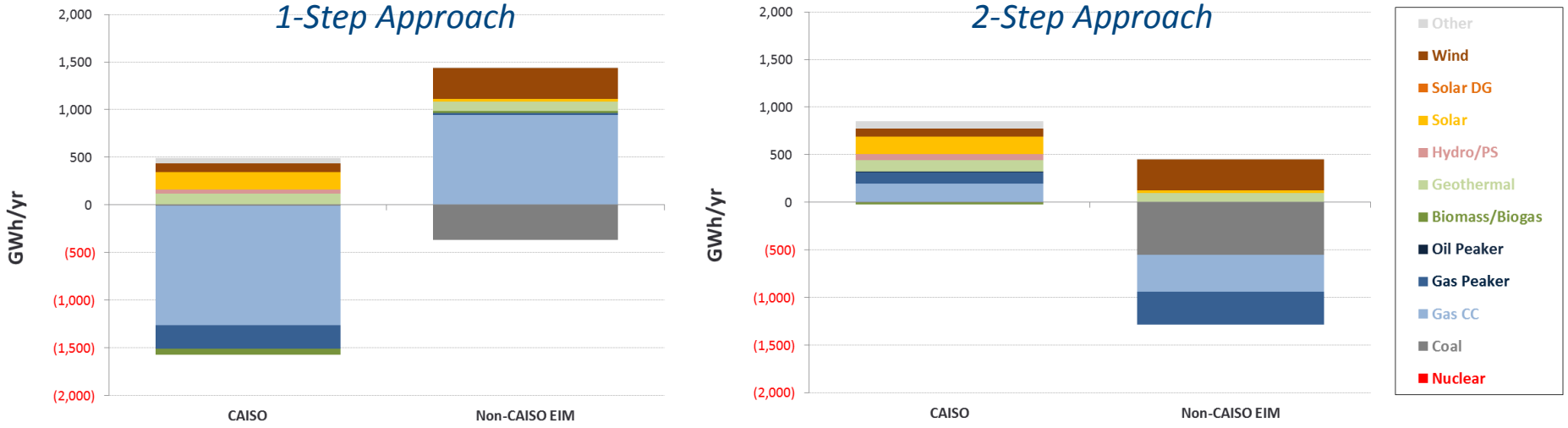
Summary of Simulation Results

EIM Generation Shifts Relative to No EIM

Both 1-Step and 2-Step EIM dispatches show an overall decrease in coal generation and increase in renewables relative to simulation of market without EIM

- Coal generation is slightly higher in the 1-Step approach than in the 2-Step approach due to secondary dispatch and resource backfilling
- Renewable generation is higher in both EIM cases due to decreased curtailments facilitated by EIM
- Under the 1-Step approach, gas plants in CAISO ramp down and are replaced by external gas generation that comes in without CO_2 costs due to secondary dispatch effects
- Under the 2-Step approach, efficient gas plants in CAISO ramp up as they can compete with external generators more fairly in the absence of secondary dispatch effects

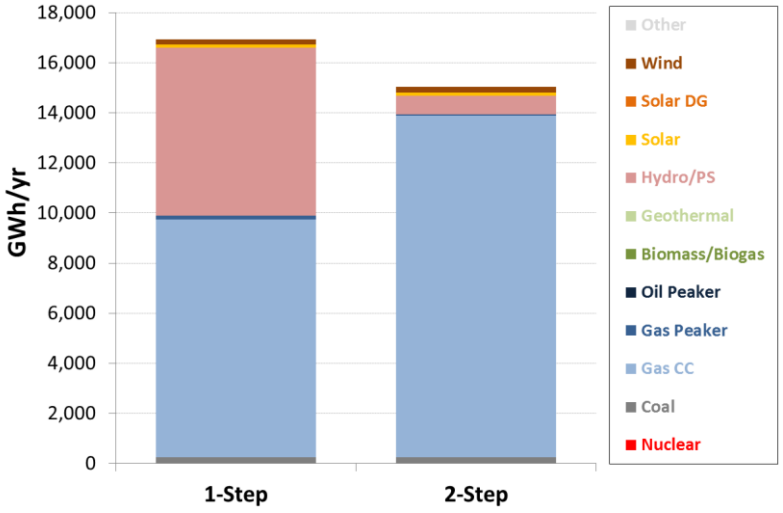
Change in EIM Generation Output Compared to a Baseline Simulation without EIM



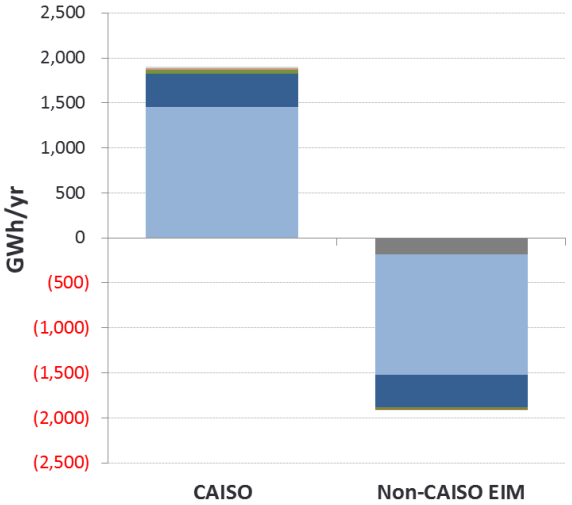
EIM Dispatch & Transfers Attributed to Serve CAISO Load

- With the 1-Step approach, EIM transfers to serve ISO load are ~5,700 GWh of hydro as EIM hydro generation does not face carbon costs to serve CAISO load
- The 2-step approach reduces such secondary dispatch and resource backfilling
  - Results in a 1,900 GWh decrease in EIM transfers to serve ISO load and shifts attribution from hydro to gas CC
  - Internal CAISO generation makes up for the decreases in transfers to serve CAISO load

Total EIM Transfers to Serve CAISO Load



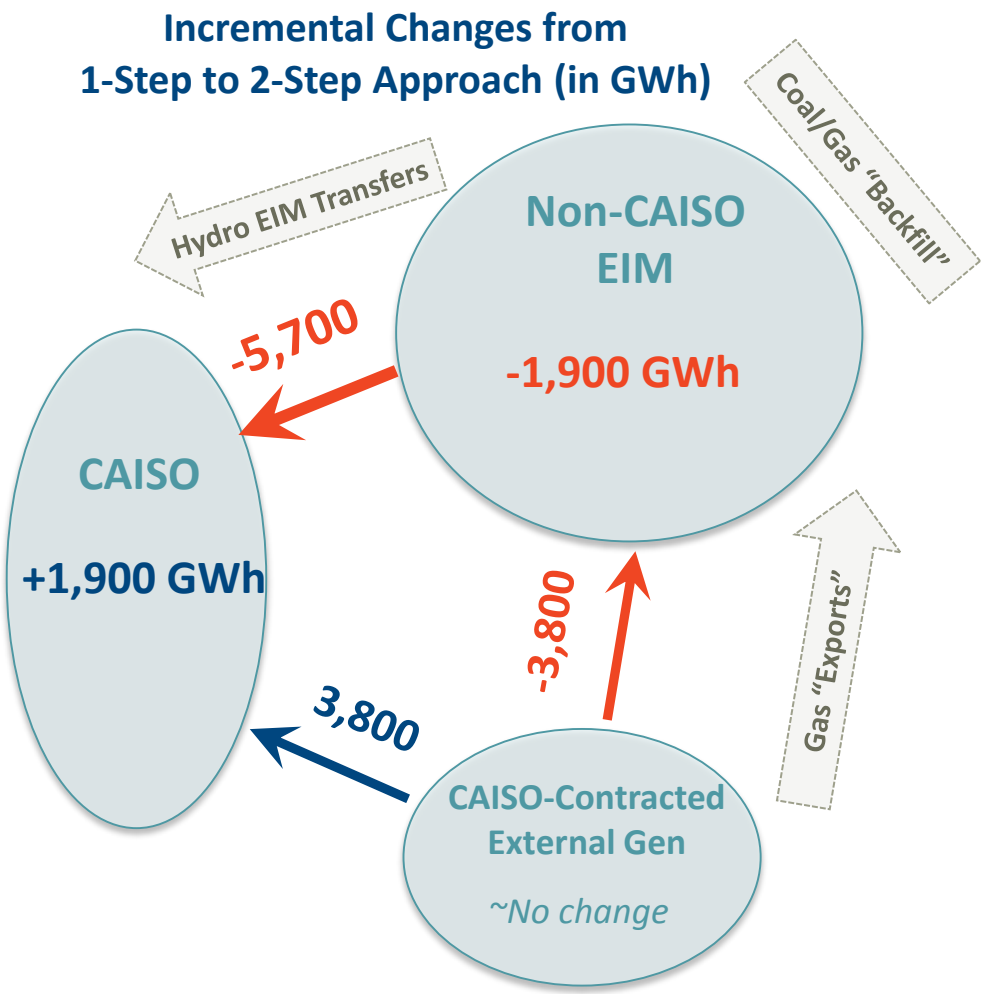
EIM Balancing-Area Generation Dispatch from 1-Step to 2-Step Approach



Changes in BA Generation and Interchanges

Compared to the existing 1-Step approach, the simulated 2-Step approach:

- Reduces hydro EIM transfers to serve CAISO load from non-CAISO EIM
- Reduces backfill dispatch in the EIM that may result under the 1-Step Approach
- Captures dispatch of gas plants needed to support CAISO load, which is not captured in 1-Step Approach due to secondary dispatch effects
  - Shifts transfers to serve ISO load from non-CAISO hydro to external CAISO-contracted generators (largely gas generation)
  - Increases CAISO-internal gas generation to make up for lower overall transfers to serve CAISO load



GHG Emission Simulation Results: EIM vs No EIM

EIM reduces overall GHG emissions in the entire region

- More flexible market-based dispatch with EIM reduces coal generation and associated emissions in both the 1-Step and 2-Step Approaches
- The 2-Step Approach slightly reduces emissions further (but mostly attributes more emissions to serving CA loads) due to reduced secondary dispatch effects

Summary of CO_2 Emissions (million tons)

	No EIM	EIM 1-Step	EIM 2-Step
CAISO Generation	50.5	47.3	49.4
Generic Imports	2.1	2.1	2.1
Generic Exports	(0.4)	(0.4)	(0.4)
EIM Imports		0.9	1.0
Total for CAISO Load	**52.1**	**49.9**	**52.1**
Rest of EIM Loads	**86.8**	**88.4**	**86.0**
EIM TOTAL	**138.9**	**138.2**	**138.1**

EIM decreases overall GHG emissions in the region

GHG Emission Simulation Results: 1-Step Approach

Simulated EIM GHG emissions with the 1-Step approach:

- Attributes *fewer* emissions to serve CAISO loads due to the secondary dispatch impacts on resources attribution
- Shows emissions *increase* outside of CAISO due to secondary dispatch/backfilling

Summary of CO_2 Emissions (million tons)

	No EIM	EIM 1-Step	EIM 2-Step
CAISO Generation	50.5	47.3	49.4
Generic Imports	2.1	2.1	2.1
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Total for CAISO Load	**52.1** →	**49.9**	**52.1**
Rest of EIM Loads	**86.8** →	**88.4**	**86.0**
EIM TOTAL	**138.9**	**138.2**	**138.1**

1-Step approach under-attributes GHG to CAISO load and over-attributes GHG to non-CAISO EIM loads

GHG Emission Simulation Results: 2-Step Approach

Simulated EIM GHG emissions with the 2-Step approach:

- More accurately captures GHG emissions that support CAISO load (at level similar to emissions to serving CAISO loads without EIM due to similar amount of contracted renewables, hydro, and gas generation)
- Shows an emissions *reduction* outside of CAISO due to decrease in coal dispatch and reduction in secondary dispatch and resource backfilling

Summary of CO_2 Emissions (million tons)

	No EIM	EIM 1-Step	EIM 2-Step
CAISO Generation	50.5	47.3	49.4
Generic Imports	2.1	2.1	2.1
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Increase in ISO-internal generation drives higher GHG emissions attributed to CAISO load with the 2-Step approach compared to the 1-Step approach

GHG emissions reduction due to decreased backfilling

2-Step approach more accurately attributes GHG to CAISO load and non-CAISO EIM loads

Conclusions

- The currently-deployed 1-Step Approach creates opportunities for some secondary dispatch and backfilling, and under-allocates external emissions to CAISO load
- Magnitude of 2-Step's benefits depends on market conditions:
  - Dispatch and emissions benefits of 2-Step Approach could be ***higher*** than what we simulated, particularly in a world in which natural gas prices are lower relative to coal
  - Our simulations with the WECC model for 2020 show conservatively low emissions benefits from the 2-Step Approach (because we have assumed gas price of ~$4.1/MMcf, which is higher than today's forecast) – this means the simulations show relatively less coal backfilling under the 1-Step Approach than what would be expected with lower gas prices

Appendix: Additional Modelling Assumptions

Simulating Load and Renewable Uncertainty

Real-time schedules for load and renewable generation were simulated by shifting hourly Day-Ahead (DA) profiles; DA and Real-Time (RT) differences were then scaled to align with typical DA forecast errors

- Simulating EIM requires RT loads and renewable generation that differ from their DA value.
  - Used hourly DA schedules from a week earlier (sifting a full week maintains weekday/weekend patterns)
  - Applied a 30% scalar for load and 50% scalar for renewables to produce DA-RT deltas that are consistent with historical day-ahead forecast errors
- Resulting DA-RT differences approximately match standard deviation of DA-RT forecasting errors as reported in a 2012 NREL report (2.6% for load and 13% for wind generation)

Contact Information

JUDY CHANG
Principal | Boston
Judy.Chang@brattle.com
+1.617.234.5630

KAI VAN HORN
Associate | Boston
Kai.VanHorn@brattle.com
+1.617.234.5222

JOHANNES P. PFEIFENBERGER
Principal | Boston
Hannes.Pfeifenberger@brattle.com
+1.617.864.7900

ONUR AYDIN
Senior Associate | San Francisco
Onur.Aydin@brattle.com
+1.415.217.1084

MARIKO GERONIMO AYDIN
Senior Associate | San Francisco
Mariko.Geronimo@brattle.com
+1.415.217.1015