Cambridge, MA| Jan 17, 2019

Harmonized Stochastic Techno-Economic Assessment and Policy Analysis for Alternative Fuels

Juju (Zhishen) Wang

CAAFI SOAP Webinar

Agenda

Part I: Techno-Economic Analysis Implementation

Part II: Policy Modeling Analysis

What is a Stochastic Techno-Economic (TEA) Model?

- **Techno-Economic Assessment** - Financial evaluation of a specific project, can be used to quantify the likelihood of financial viability.

Net Present Value - the value of all future cash flows, discounted to nominal dollars in the base year. In general, a project NPV greater than zero indicates a financially viable project, and a NPV below zero indicates a project that is not financially viable.

Minimum Selling Price - the lowest price at which the fuel product must be sold in order to have a project Net Present Value of zero at the stipulated rate of return. Note that when determining the MSP, the middle distillates (diesel and jet) benefit from the premium added.

- **Stochastic** - Incorporates distributions so that uncertainties can be quantified

Technology/Pathway Cases

Process	Feedstock
Micro - Fischer-Tropsch	Forest residues
HFS-SIP	Sugarcane
HEFA	Waste fats, oils and greases (FOG)
HEFA	Palm oil/palm fatty acid distillates (PFAD)
Fischer-Tropsch	Municipal solid waste
ATJ (via. iBuOH)	Corn

These pathways have been chosen as they are mature technologies. They also incorporate a wide variety of technologies that are used around the globe.

Research Question

There have been previous techno-economic assessments for each of these pathways. However, they vary in key factors:

- Lifetime of the facility
- Production capacity
- Key financial assumptions
- Input costs, such as natural gas, power, and feedstock costs
- Quantification of uncertainty (or lack thereof)

This research aims to evaluate them using harmonized metrics in order to compare across pathways on a level playing field. Further analysis is done through quantifying how potential policies may impact each pathway.

Harmonized Financial Assumptions

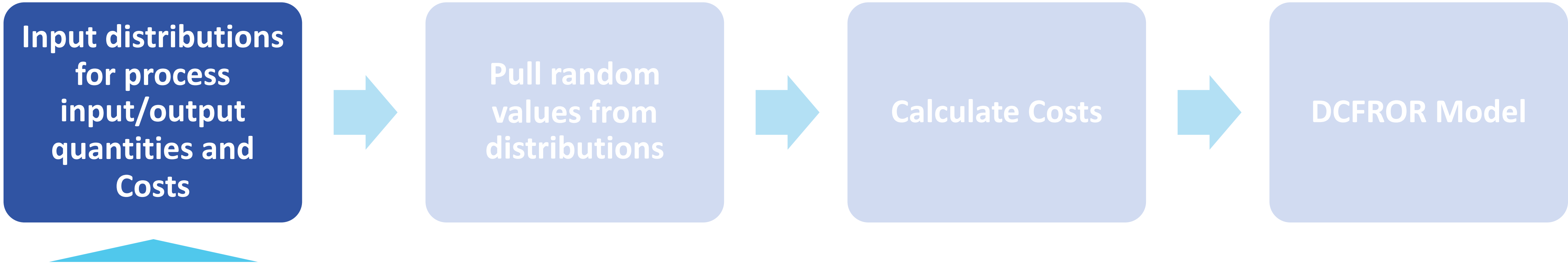
Equity	40%
Cost of Equity	15%
Deterministic Capacity	2000 barrels per day (111.3 million liters/year)
Capacity Factor	95%
Construction and start-up period	3 years

Pathway	**Fixed Capital Investment Cost (millions)****
Micro FT (Wood Residue)	317.5
SIP (Sugarcane)	197.3
HEFA (FOG)	62.5
HEFA (PFAD)	62.5
FT (MSW)	264
ATJ via. iBuOH (Corn)	178

** Note that these are the determinate values. Actual FCI used are randomly generated values from distributions drawn around these.

PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Stochastic Techno-economic Model



Input distributions for process input/output quantities and Costs

Pull random values from distributions

Calculate Costs

DCFROR Model

Distributions Include

Process input/output quantities
- Fuel yield
- Natural gas input
- Power input
- Other inputs (e.g. catalysts, water etc…)*

Costs
- Feedstock cost
- Fixed capital investment
- Fuel cost
- Natural gas cost
- Power cost
- Other input costs

Feedstock Input (fixed)

*Varies based on pathway

Stochastic Techno-economic Model

Input distributions for process input/output quantities and Costs

Pull random values from distributions

Calculate Costs

DCFROR Model

Stochastic Techno-economic Model

Input distributions for process input/output quantities and Costs

Pull random values from distributions

Calculate Costs

DCFROR Model

Calculated costs include

- Direct Operating Cost
- Various Operating Costs
- Fixed Capital Investment
- Total Feedstock Costs
- Total Fuel Sales
- Other Sales (e.g. DDGS, power, etc…)*

*Varies based on pathway

Stochastic Techno-economic Model

Input distributions for process input/output quantities and Costs

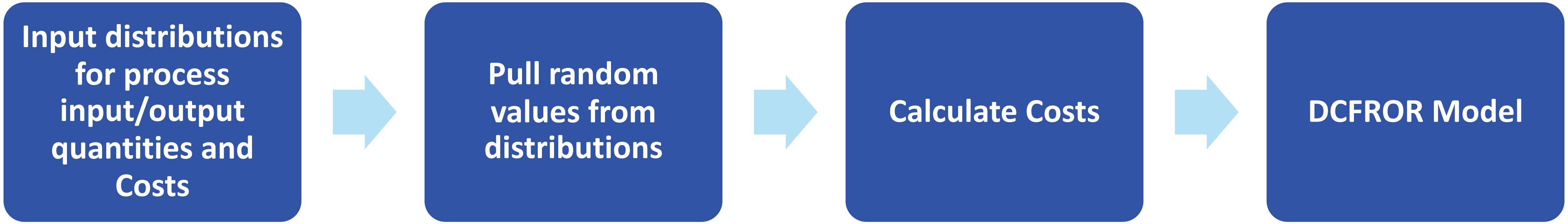
Pull random values from distributions

Calculate Costs

DCFROR Model

The discounted cash flow rate of return model calculates **net present value** (NPV) and **minimum selling price** (MSP) over a 20 year facility lifetime

Stochastic Techno-economic Model



Input distributions for process input/output quantities and Costs

Pull random values from distributions

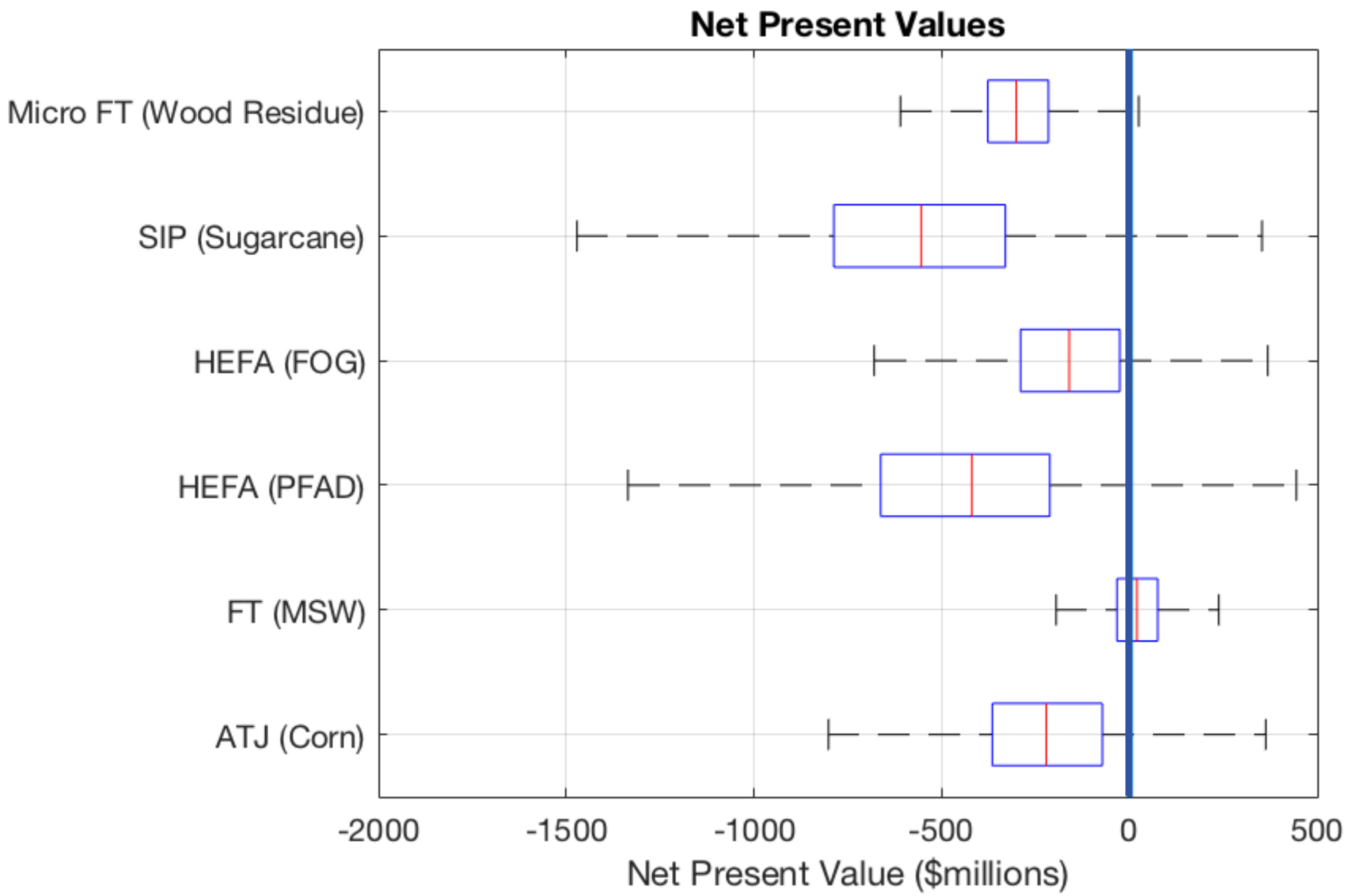
Calculate Costs

DCFROR Model

- This process is repeated 10000 times to quantify uncertainty
- The model used is modified from Bann et al. (2017)

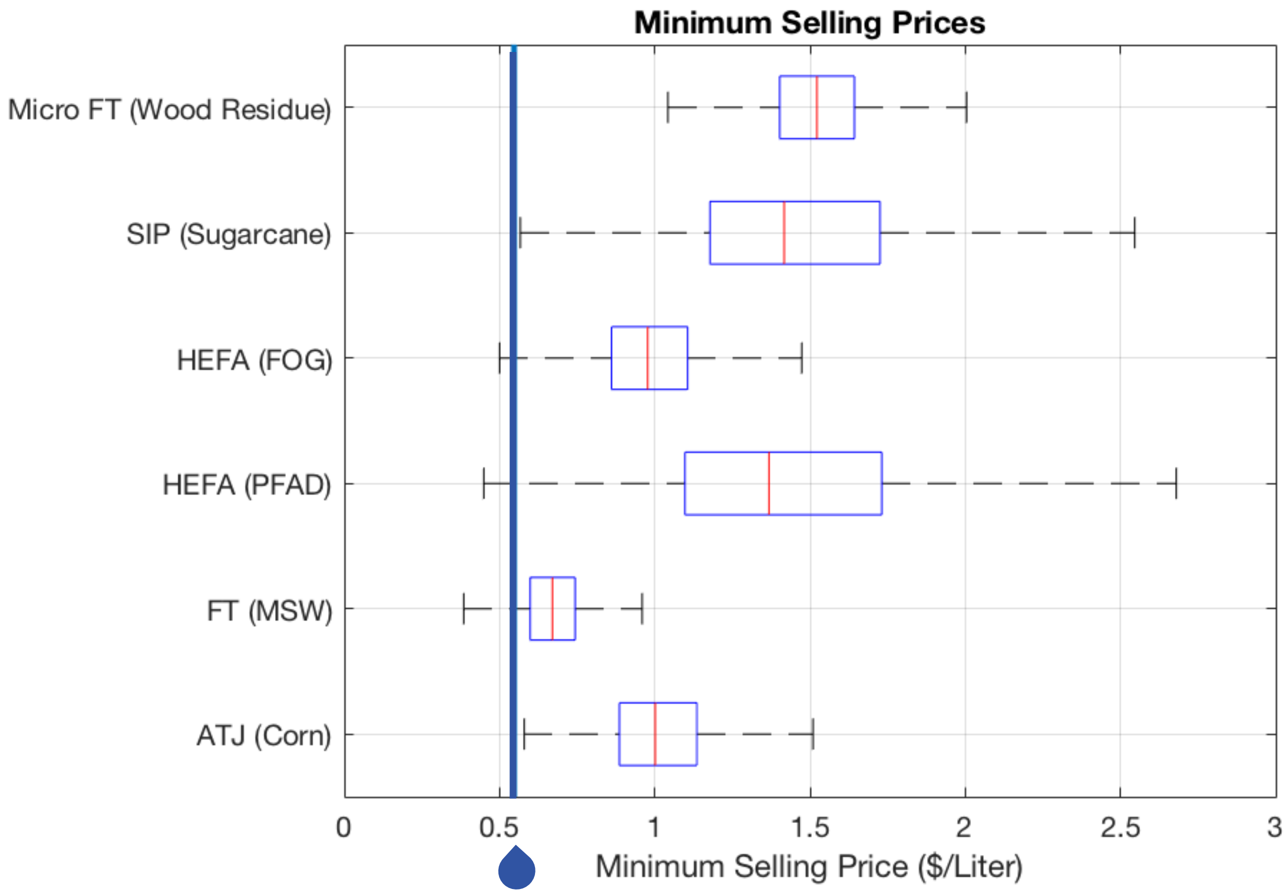
TEA Results

Baseline Net Present Value Results



PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Baseline Minimum Selling Price Results



Jet Fuel price taken from
the IATA Jet Fuel Price
Monitor ($0.56/liter)

PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Policy Implementation

Policy Cases

Policy	Effect	Example Policy
Output Based Incentive (Output Subsidy)	Monetary credit based on the amount of fuel produced on a per liter basis. All fuel products (not only jet) benefit from this policy.	RFS2 Rins
Input Subsidy	Feedstock costs reduced by a fixed percentage.	Subsidizing price of feedstock
Capital Grant	FCI is reduced. This is awarded as a lump sum at the beginning of facility construction. The capital grant does not exceed the FCI of the facility.	DOE or DOD programs that grant a lump sum to facilities
GHG emission reduction-defined incentive	monetary credit based on the amount of CO_2 equivalent reduced. Granted as a lump sum based on fuel output. **	California LCFS, CORSIA

**Two cases are considered: one in which all fuel products generate the credit, and one in which only jet products do. (Reduction in emissions is based on LCA values agreed to by ICAO or our best estimate of these values.)

Policy Implementation

What values should we select for these policies?

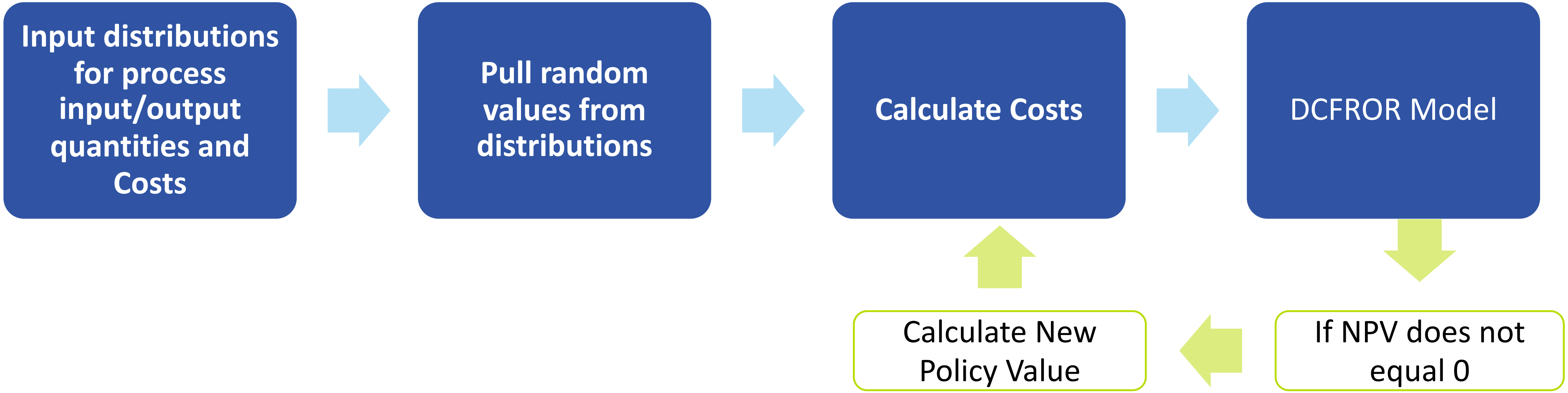
These policies were implemented in 3 different ways

- Breakeven implementation
- Possible real world example case
- Equal cost implementation

Breakeven Policy Implementation

Breakeven Policy Implementation

1. Starts with policy value of 0
2. If NPV does not equal 0…
3. The code takes the NPV value estimates what the policy amount should be.
4. And repeat until NPV is ~0



Input distributions for process input/output quantities and Costs

Pull random values from distributions

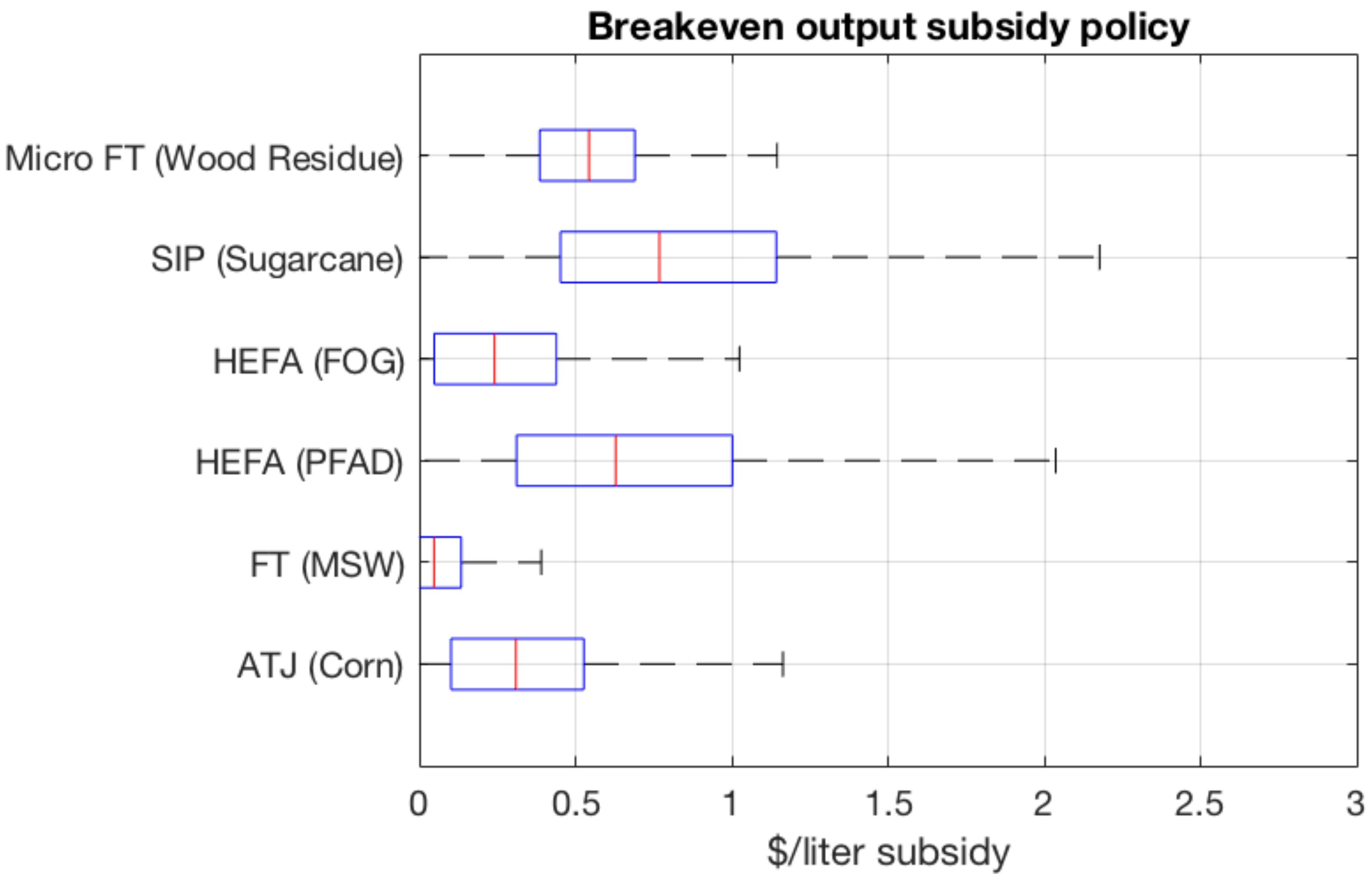
Calculate Costs

DCFROR Model

If NPV does not equal 0

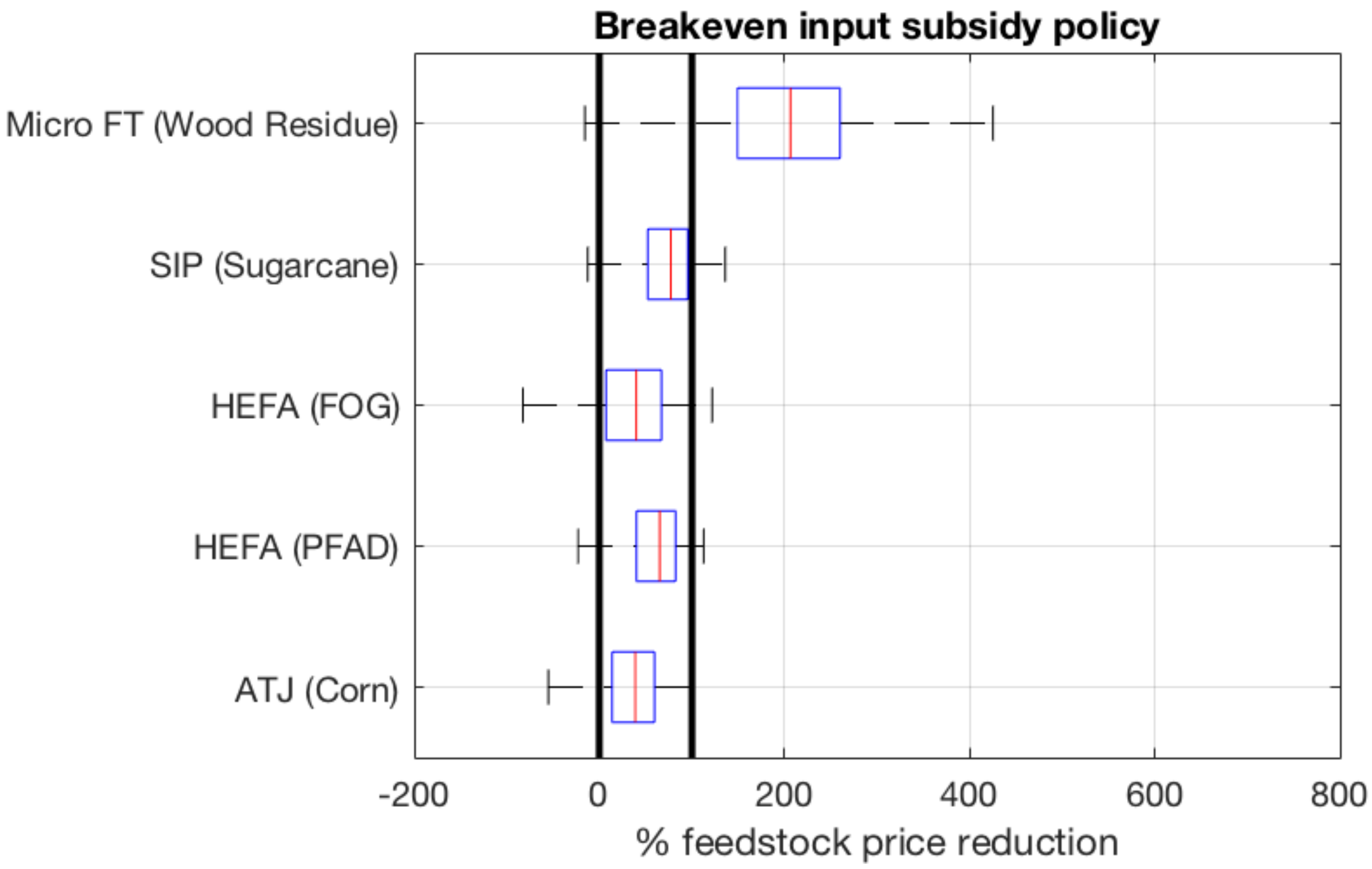
Calculate New Policy Value

Breakeven Output Subsidy Policy



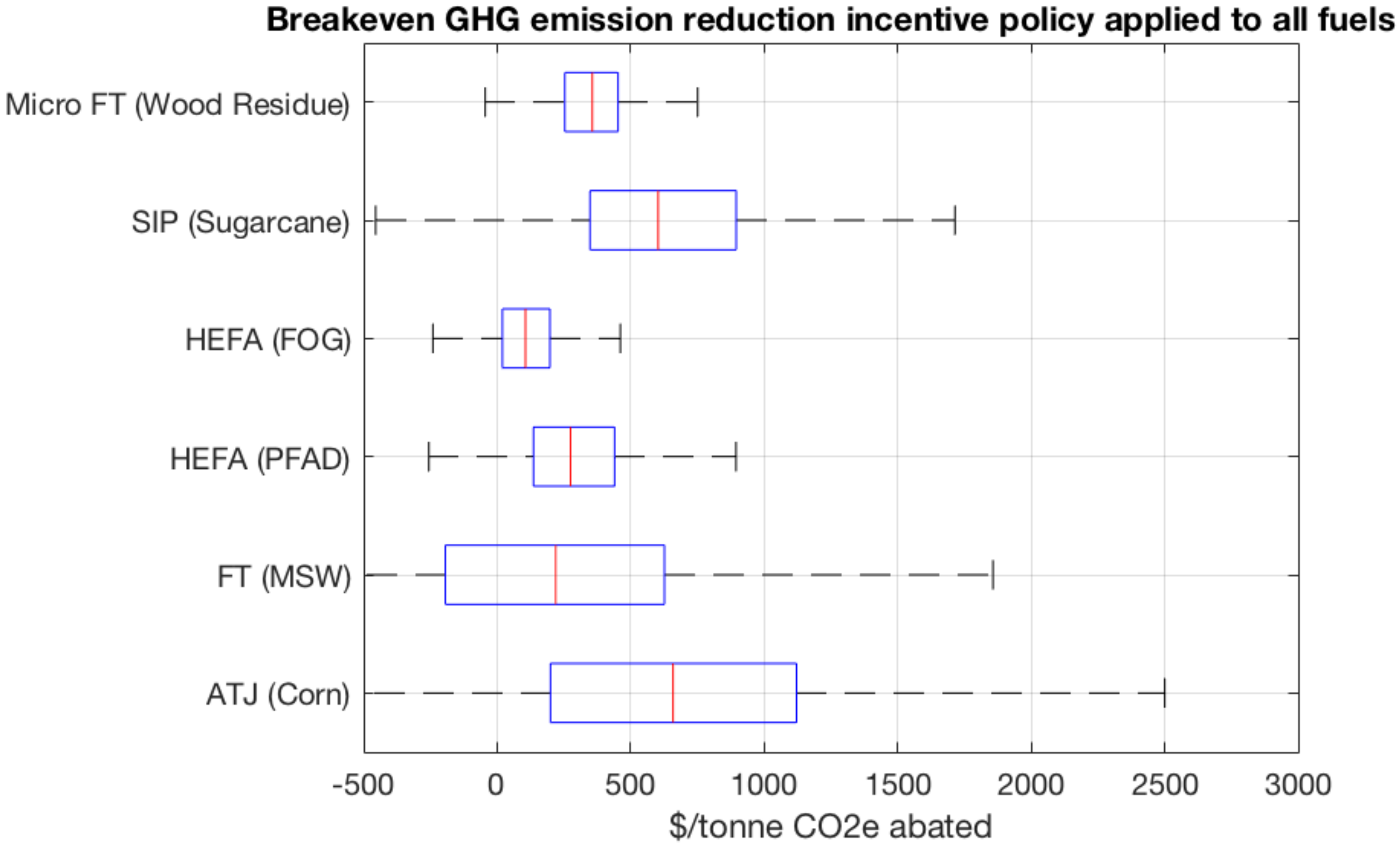
PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Breakeven Input Subsidy Policy



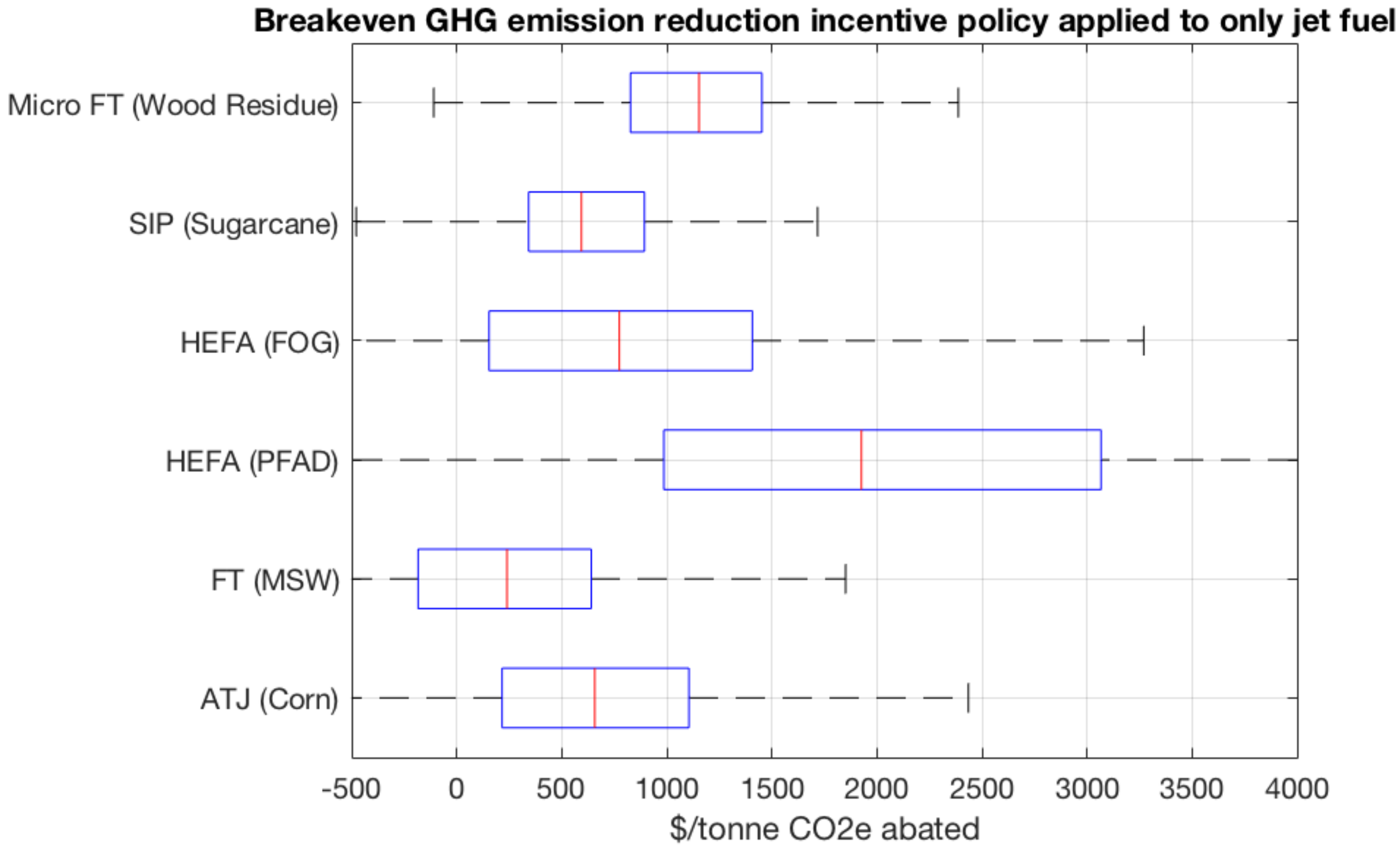
PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Breakeven GHG Emission Reduction Incentive Policy (All fuels)



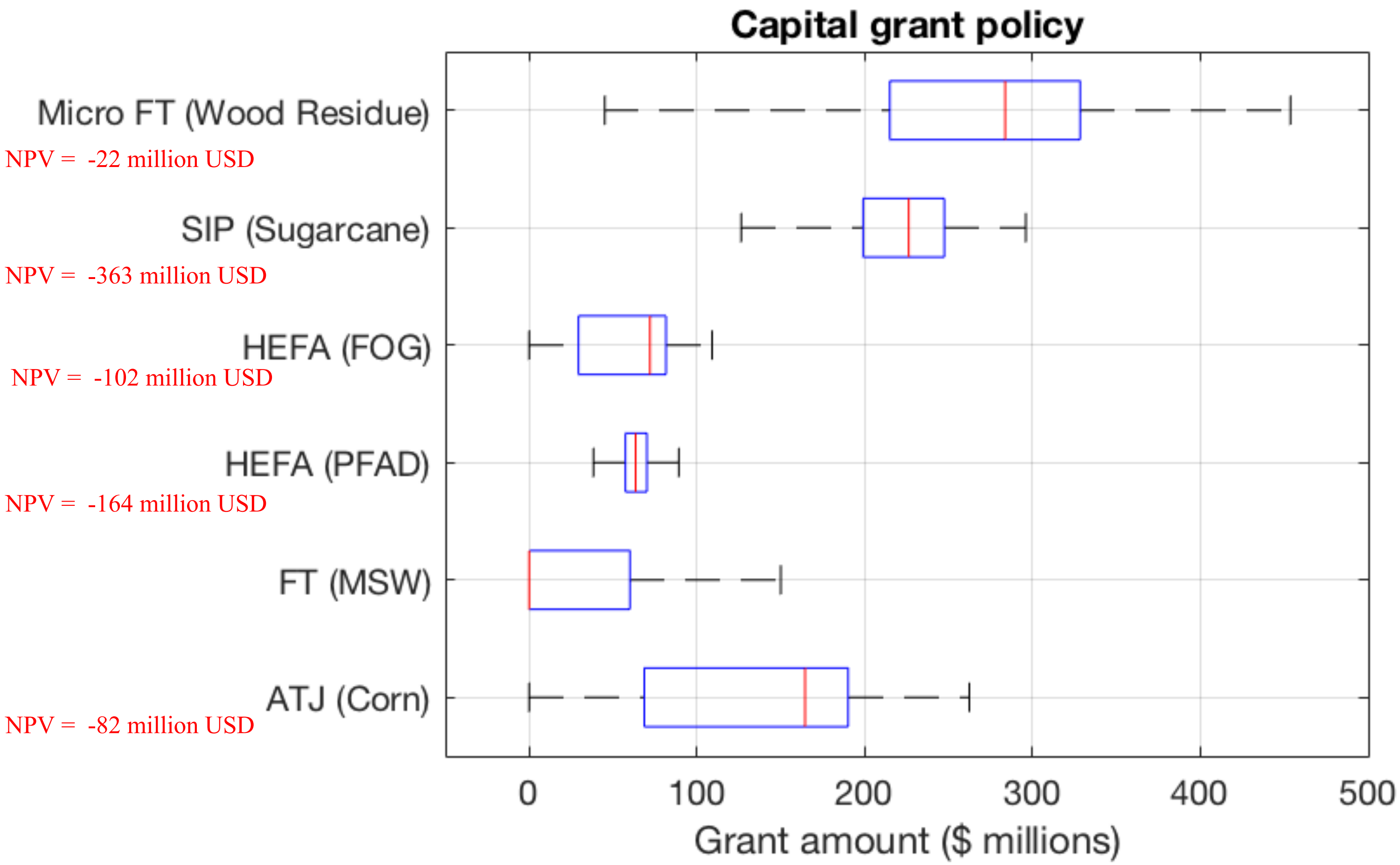
PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Breakeven GHG Emission Reduction Incentive Policy (Jet Only)



PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Breakeven Capital Grant Policy



NPV = -22 million USD

NPV = -363 million USD

NPV = -102 million USD

NPV = -164 million USD

NPV = -82 million USD

Maximum size of the capital grant is capped at the total FCI in each model run.

In many cases, a capital grant alone was not enough to increase NPV above zero in the median case.

For these pathways, the resulting median NPV, which is still negative, is shown in red

PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Summary of Breakeven Policy

- In all cases except for capital grant policies, it is possible to reach a median NPV of 0 for every pathway.
- Even when the entire fixed capital investment cost is covered through a capital grant, some pathways still have a negative NPV
- The input subsidy required to achieve a breakeven price can be over 100% of the feedstock price.
- For a breakeven case, the policy value for GHG emissions reduction incentive when applied only to jet fuel is very high

Policy Scenario Examples

Policy Scenario Examples Implementation

This analysis shows the effect potential policies can have as well as how the policies interact with each other.

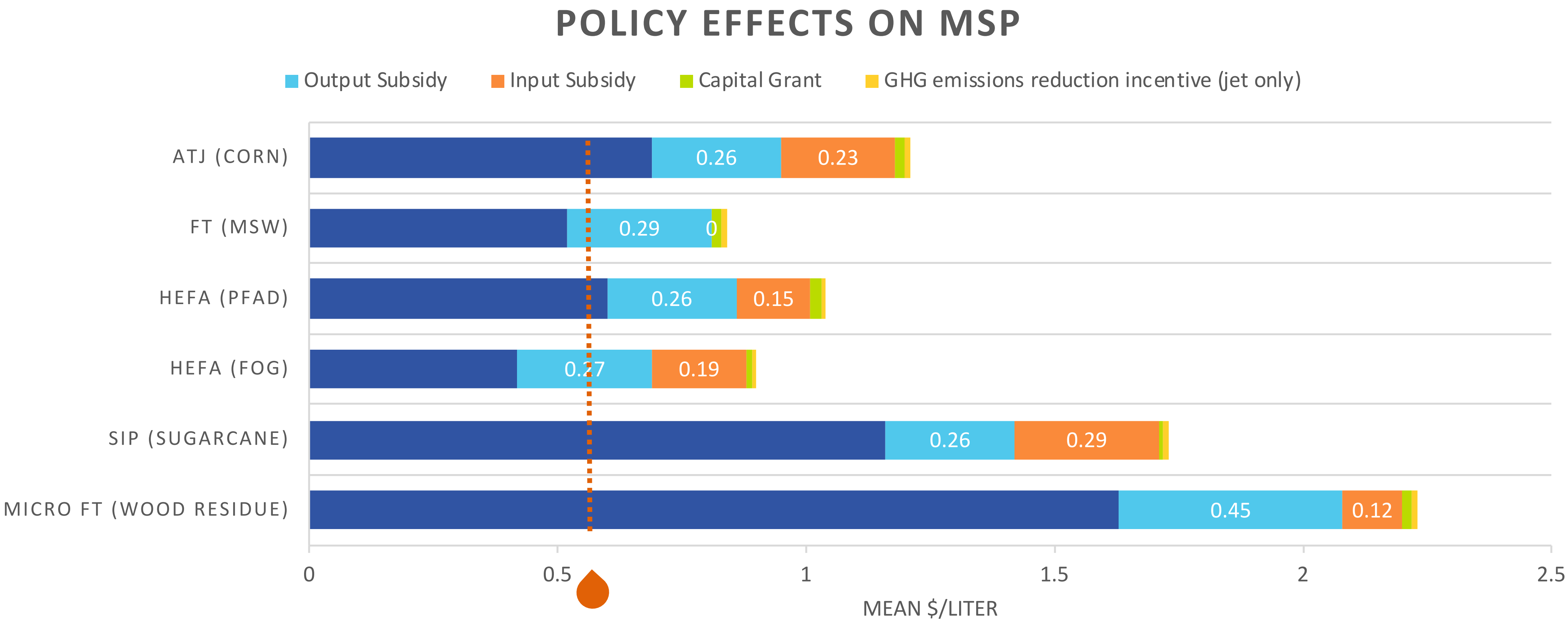
Methodology:

1. Research what reasonable policy ranges could be
2. Implemented the combined policies as well as each policy individually

The policies implemented:

Output Subsidy (RFS RIN values)	**Input Subsidy (Data from Indonesia)**	**Capital Grant (DOD funding program)**	**GHG Emissions Reduction Incentive - Jet only (CORSIA)**
0.25 $/Liter	27% feedstock cost subsidy	50 mil. USD capital grant	8 USD/t_{CO2} reduction credit (20 USD/t_{CO2} by 2035)

Example Policy Scenarios



Jet Fuel price taken from the IATA Jet Fuel Price Monitor ($0.56)

PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Key takeaways from policy scenario examples

- These policies stack – when combined, the effect of the policies are added.

- In some cases, these policies combine to give a MSP less than the price of jet fuel today.

Equal Cost Policy Implementation

Equal Cost Policy Implementation

1. A value was chosen for an output subsidy
2. The total cost to the government of the policy was calculated (net present value over the 20 year span)
3. From this, values for input subsidy, capital grant, and emissions based incentive policies were calculated.
4. These policy values were used to run their respective policy cases.

Equal Cost Policy (HEFA FOG Pathway Example)

Policy Type	Output Subsidy	Input Subsidy	Capital Grant	GHG Emissions Reduction Incentive
Policy	0.10 $/Liter	16% feedstock cost subsidy	77 mil. USD capital grant	48 USD/tonne
Total policy cost (mil. USD) [Standard Deviation]	77 [3]	77[19]	77 [4]	77 [3]
MSP ($/liter) [Standard Deviation]	0.97 [0.19]	0.98 [0.17]	0.88 [0.19]	0.97 [0.19]

Now let's try some other output subsidy values!

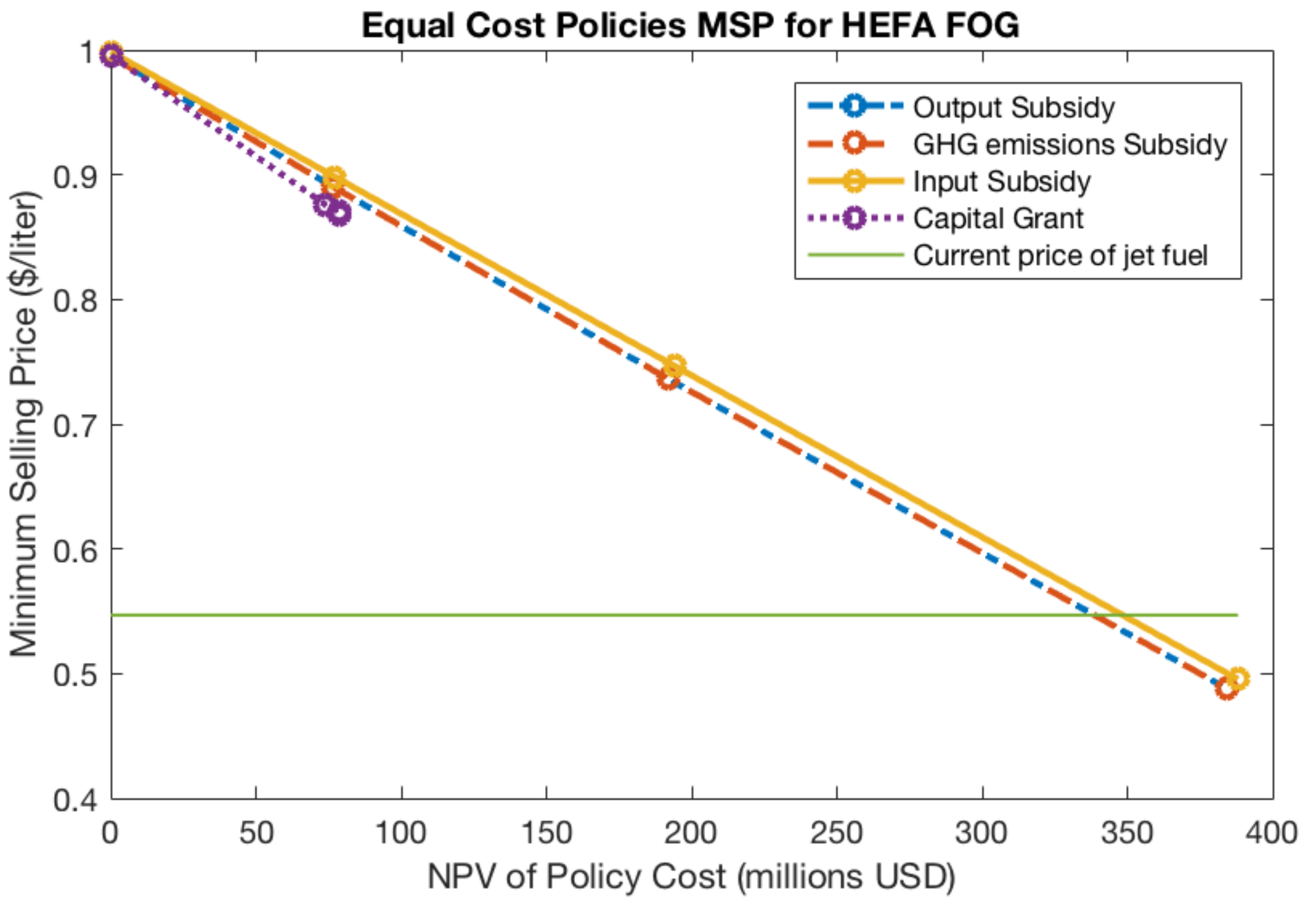
Equal Cost Policies (HEFA FOG Pathway)

Policy type	**Output Subsidy**		
Policy ($/liter output subsidy)	0.10	0.25	0.75
Total policy cost (mil. USD) [Standard Deviation]	77 [3]	192 [8]	576 [23]
MSP ($/liter) [Standard Deviation]	0.97 [0.19]	0.82 [0.19]	0.32 [0.19]
Policy type	**Input Subsidy**		
Policy (subsidy on feedstock costs)	16%	40%	119%
Total policy cost (mil. USD) [Standard Deviation]	77 [19]	192 [50]	571 [146]
MSP ($/liter) [Standard Deviation]	0.98 [0.17]	0.81 [0.12]	0.25 [0.05]
Policy type	**Capital Grant**		
Policy (capital grant in mil. USD)	77	79*	79*
Total policy cost (mil. USD) [Standard Deviation]	77 [4]	79 [9]	79 [9]
MSP ($/liter) [Standard Deviation]	0.88 [0.19]	0.87 [0.19]	0.87 [0.19]
Policy type	**GHG Emissions Reduction Policy**		
Policy (USD/tonne CO_2 reduction credit)	48	114	343
Total policy cost (mil. USD) [Standard Deviation]	77 [3]	192 [8]	576 [23]
MSP ($/liter) [Standard Deviation]	0.97 [0.19]	0.82 [0.19]	0.32 [0.19]

* These hit the maximum capital grant value

PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Equal Cost Policies Plot for HEFA (FOG)



PRELIMINARY DATA, PLEASE DO NOT CITE OR QUOTE

Takeaways

- All policies modeled have a linear affect. For example, when the cost of the policy is doubled, the impact on the MSP is also doubled.
- Three policies: Input subsidy, output subsidy, and GHG based incentive policies, have identical effects on the mean minimum selling price.
- Capital grant is most effective at reducing mean MSP because the benefit of the policy to the fuel producer is not taxed.
- The variance of the MSP changes in the input subsidy case. This is because the input subsidy is given as a percentage of the total cost. The policy takes on some of the burden of varying feedstock costs.
- Coupled with the fact that the policies stack, the impact of any combination of the four policies considered can be approximated at different levels than those explicitly quantified here.

Limitations

- The model has simple implementation of policies. It doesn't take into account policy variations over the 20 years or stochastic variation in the policy (i.e. policy could increase/decrease every year by an unknown amount)
- This study is a nth plant analysis. Costs are uncertain for commercialized facility and technology maturity has not been taken into account.
- An important part of the facility net present value calculation takes into account future fuel prices. We can only give our best prediction of what those may be.

Next Steps

- Verify our TEA model with researchers at Purdue University
- Model more complex policies that deal with risk reduction such as off-take agreements and loan guarantees
- Include additional pathways such as the waste gas to ethanol ATJ

Thank you!

This project is a co-operative effort between MIT, Purdue, and the University of Hasselt (Belgium).

Acknowledgements

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through **ASCENT**, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, **Project 1** through FAA Award Number 13-C-AJFE-MIT under the supervision of **James Hileman, Daniel Williams** and **Nathan Brown**. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

MIT LABORATORY FOR
AVIATION AND
THE ENVIRONMENT

Juju Wang
jujzwang@mit.edu