Techno-economic Assessment Methodology and Results

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- Benjamin Vegel
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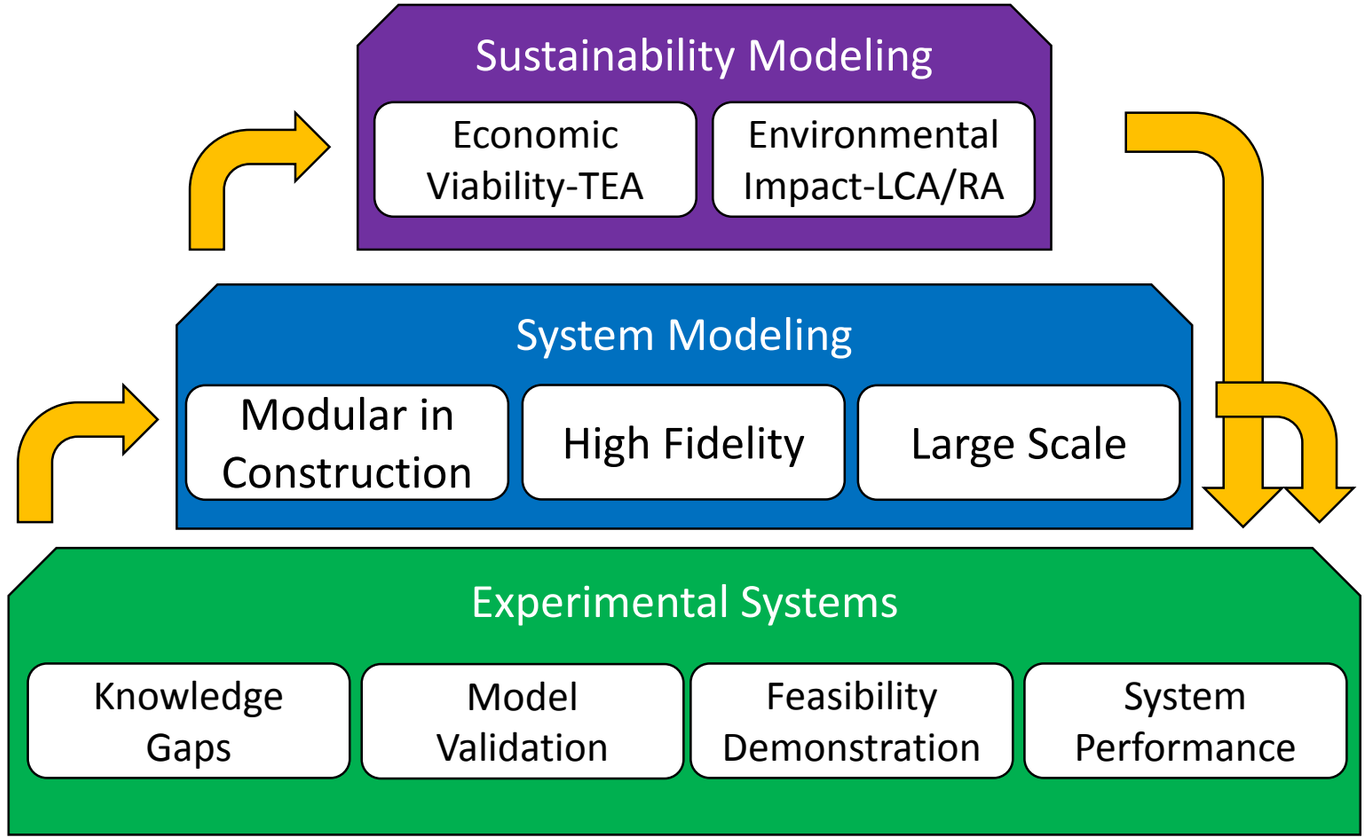
- Meeting organizers

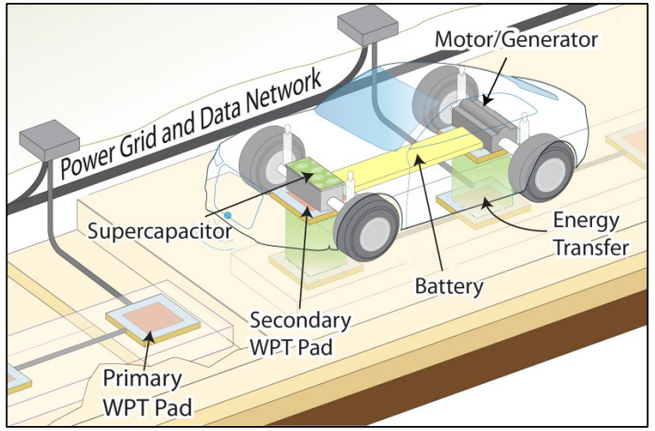
General Approach



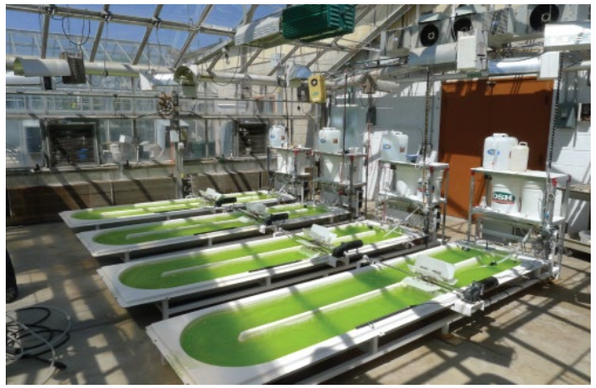
Technology Space

Energy

WPT for Transportation



Microalgal Biosystem



Food

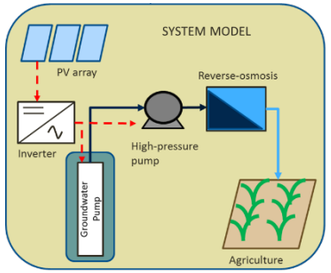
Desert Agriculture

Nuclear Power Systems

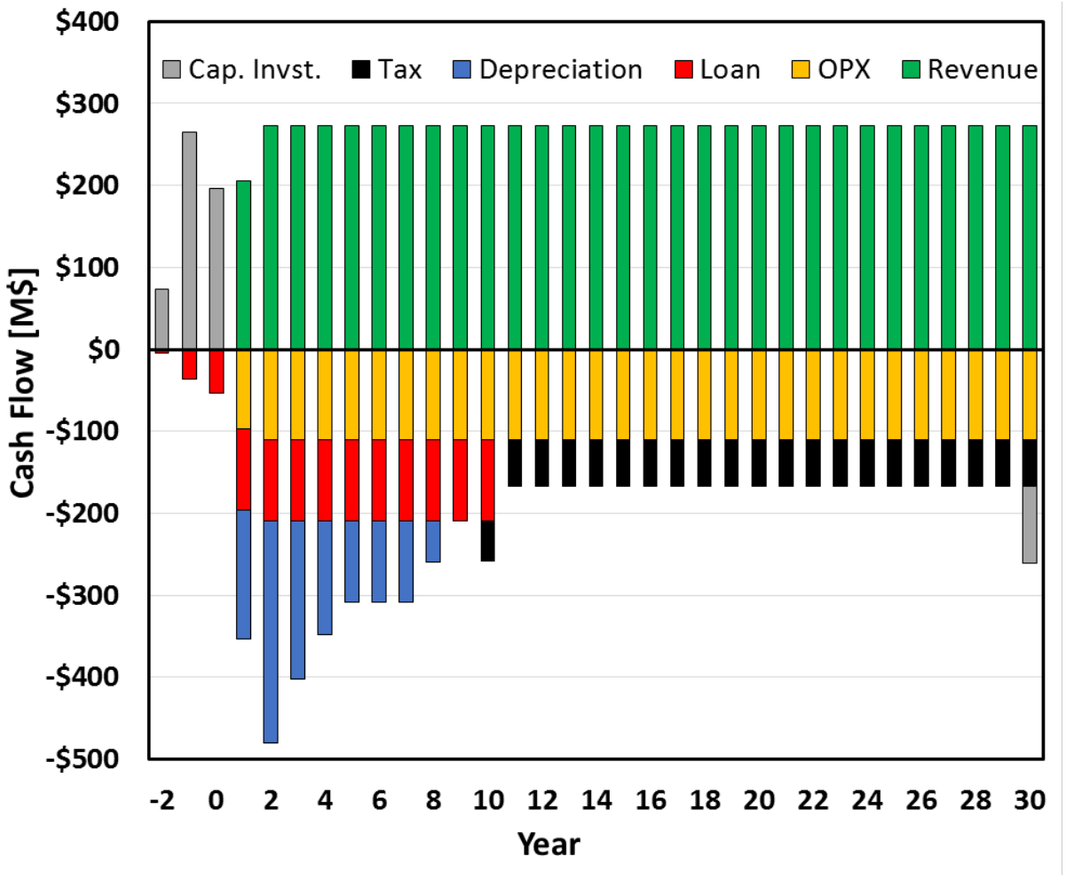
Power System Optimization

Yeast Biosystems

Water Systems



Techno-economic Methods



n^{th} Plant Assumptions	
Description	**Assumed Value**
Internal rate of return	10%
Financing debt / equity	60% / 40% of total capital investment
Plant life	30 years
Income tax rate	35%
Debt interest rate	8% annually
Term for debt financing	10 years
Working capital cost	5.0% of fixed capital investment (w/o land)
Depreciation schedule	7-years MACRS
Construction period	3 years (8% 1st yr, 60% 2nd yr, 32% 3rd yr)
Plant salvage value	No value
Start-up time	6 months
Revenue and costs during start-up	Revenue = 50% of normal Variable costs = 75% of normal Fixed costs = 100% of normal
On-stream factor	90% (330 operating days per year)
Indirect capital costs	60% of total installed downstream capital

CAPX – OPX Tradeoff

- Correlation between CAPX, OPX, and yearly revenue:

$$Breakeven\ Revenue\left(\frac{\$}{yr}\right) \approx 0.140\ * CAPX\ (\$) + (1 + 1.44\%) * OPX\left(\frac{\$}{yr}\right)$$

Fuel + Co-products + Credits

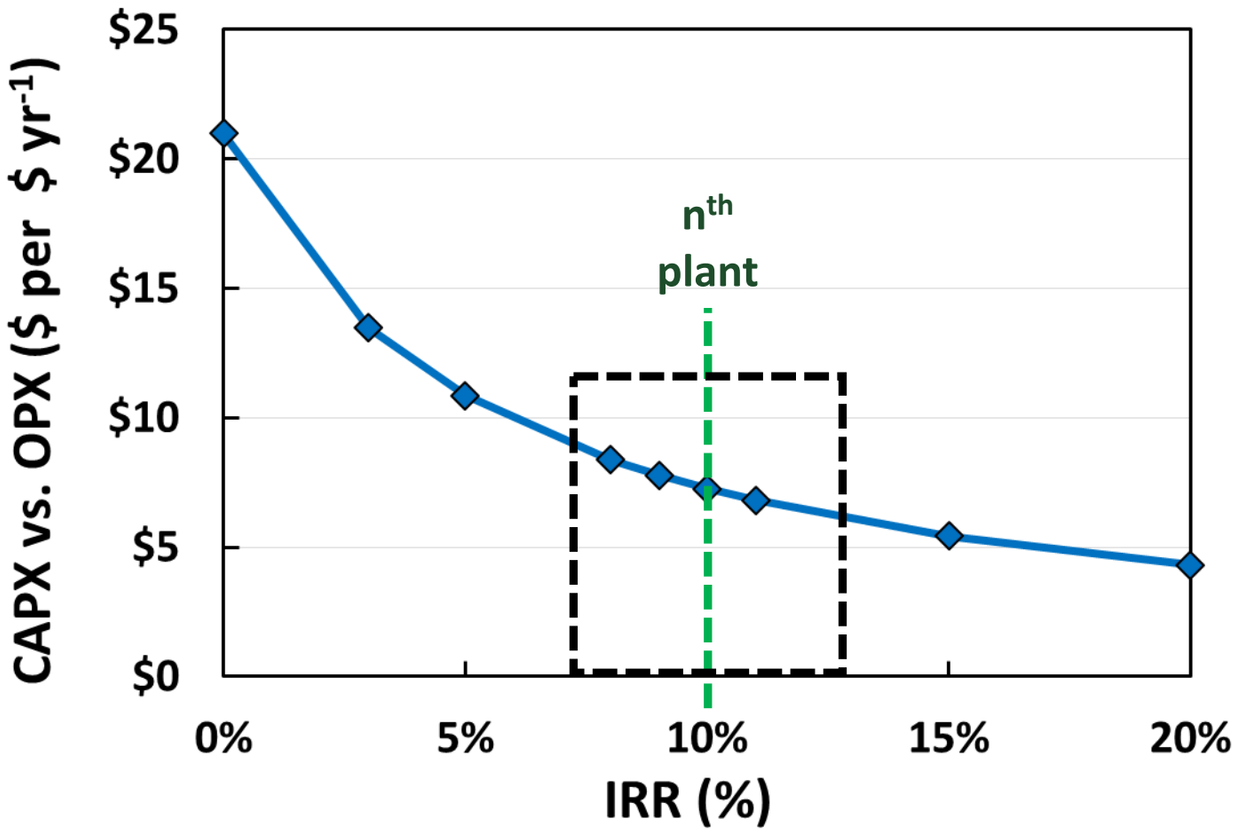
Weight of Capital: IRR, depreciation, loan interest, etc

From Year 1 start-up

CAPX – OPX Tradeoff

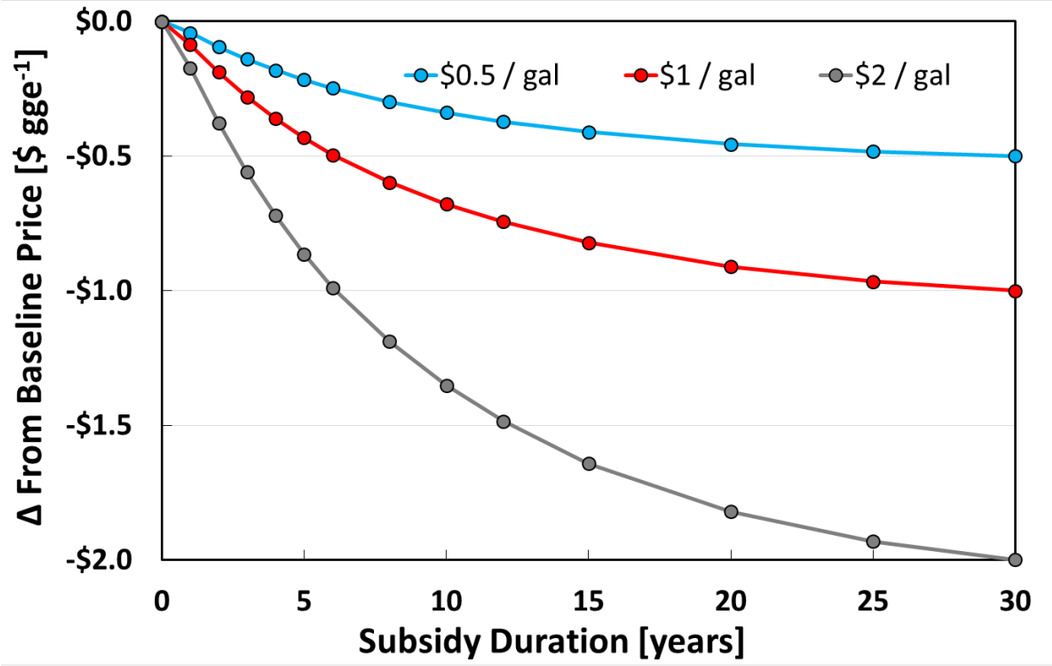
$$Breakeven\ Revenue\left(\frac{\$}{yr}\right) \approx 0.140\ *\ CAPX\ (\$) + (1 + 1.44\%) * OPX\left(\frac{\$}{yr}\right)$$

- Tradeoff of **$7.3 CAPX ≈ $1 yr^{-1} OPX**
- Ratio depends on CAPX term
  - Weight of upfront vs. recurring costs
  - Especially IRR

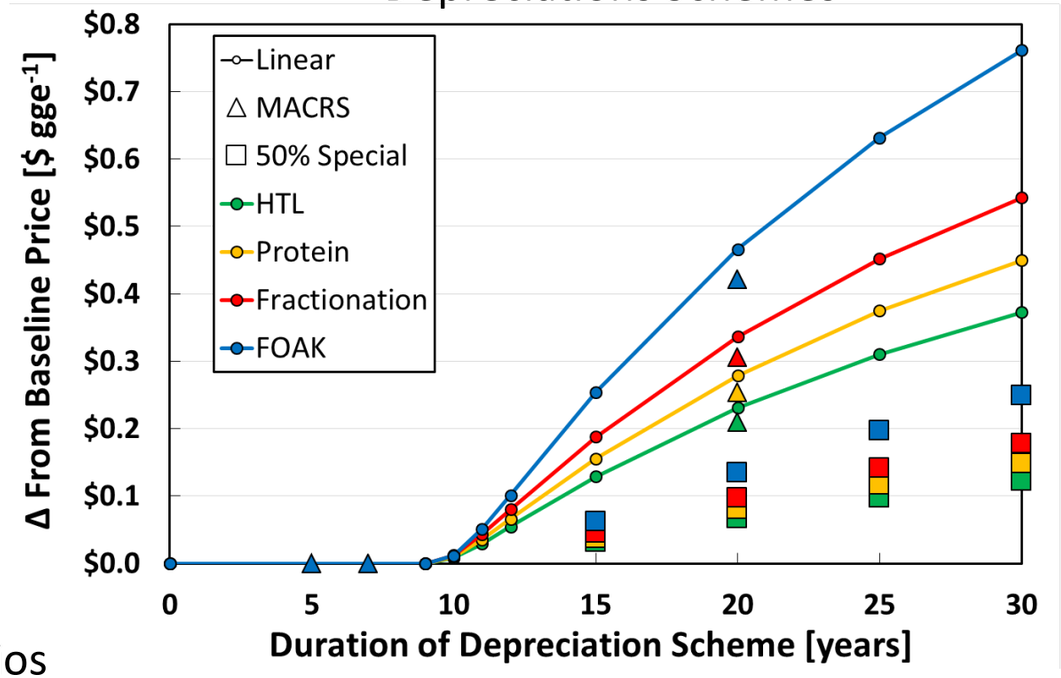


Impact of Methodology: Biofuel Example

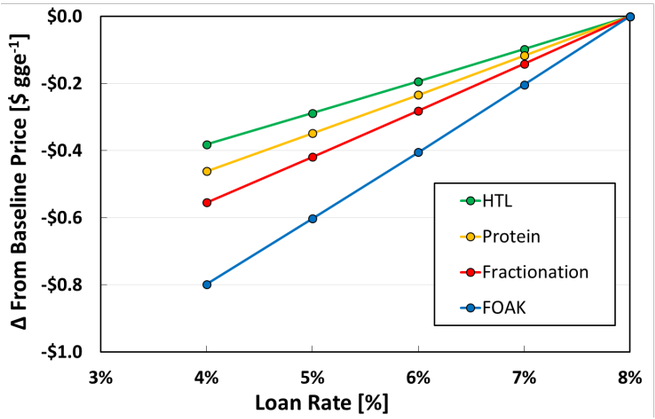
Government subsidies



Depreciations Schemes



Loan Scenarios



Techno-economic Requirements

Three Core Components

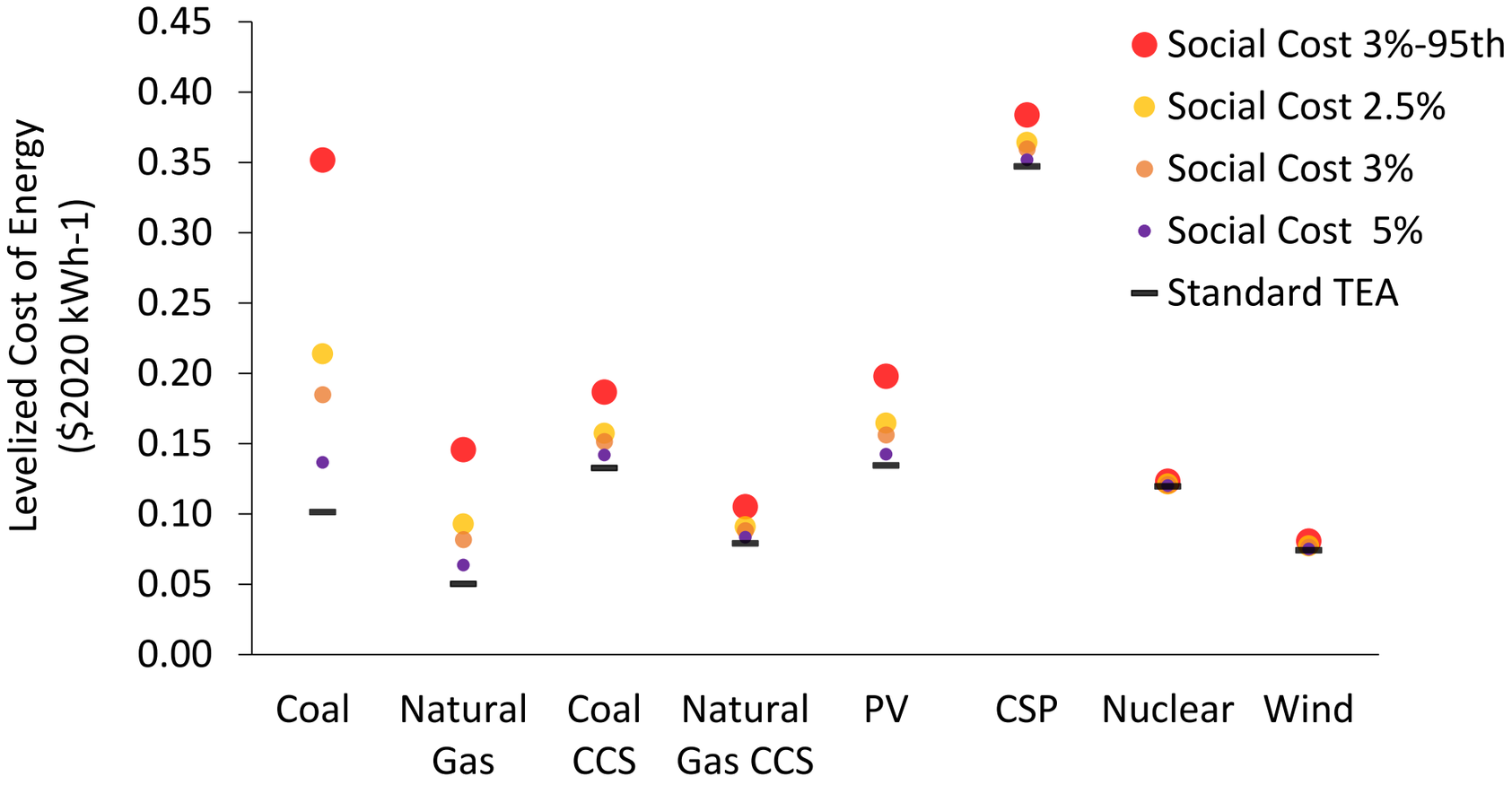
Overnight Capital Cost

Operational Cost

=

Annual Output & Products

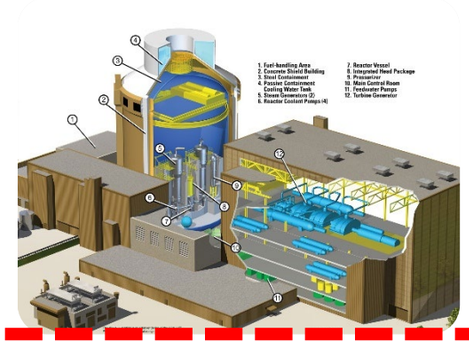
Techno-Economic Assessment



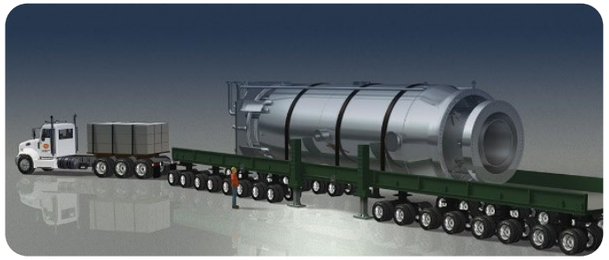
Capital Cost Estimation

Top-down Method

Existing estimates for LR



Scaling factors
Learning curves



Bottom-up Method

Materials estimates

Cost estimates

Capital Cost

Top Down: Capital Estimation

$5,460 kWe $^{-1}$
LR input

Top-down: scaling factors

Component	*n*
Building	0.5
Spent fuel management	1
Instrumentation and control	0.6
Other, electric	0.6
Other, direct	0.3
Contingency	0.55
Owner's costs	0.29
Reactor pressure vessel	1
Control rods	1
Steam generation	1
Chemical volume controls	0.667
Other, reactor	0.6
Containment	0.667
Condenser	0.72
Turbo-generator	0.8
Special equipment	0.4
Conventional indirect	0.75
Engineering	0.2
Nuclear indirect	0.5

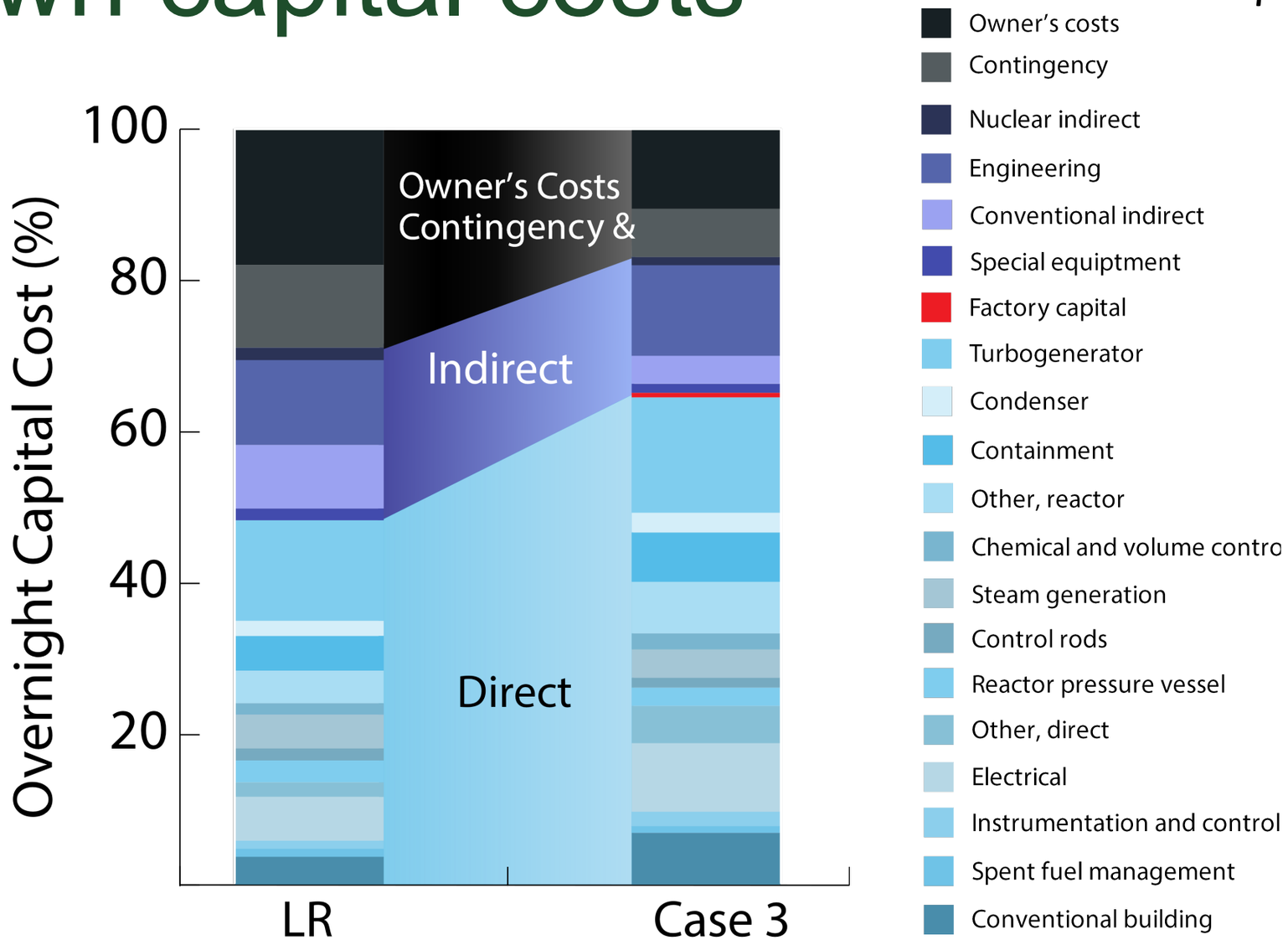
increase SMR costs

Upfront	Co-siting benefits Sharing of components
Other	Reduced contingency
Reactor	Learning curve Factory production
Generator components	Factory production integration
Construction	Construction from 6-9 years to ~3 years

decrease SMR costs

Top-down capital costs

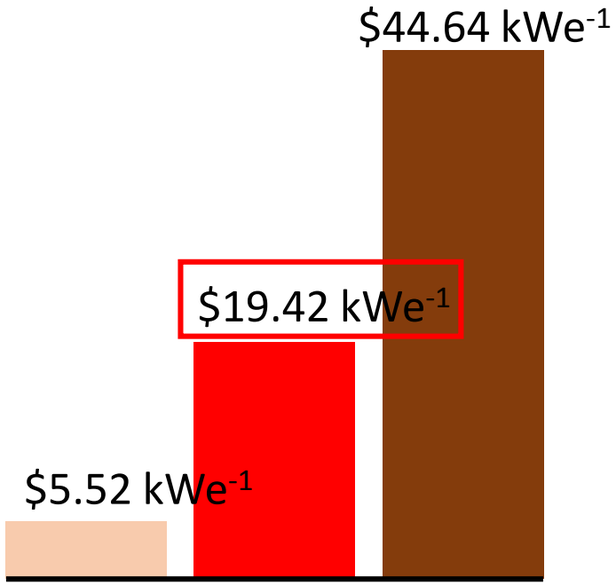
$5,576 kWe $^{-1}$



Factory facility cost addition

Input	*Parameters*
Factory capital ($/ft^2)	$200-$500
SMR dimensions	89' by 32'
Space increase factor	2x-5x
Reactor orders	58
Generator space increase	Up to 50%
Build time	2 years
Cost distribution over units	20 years
Facility capacity	6 units

- 3 cost and space scenarios
- Costs are allocated across reactors (based on demand)

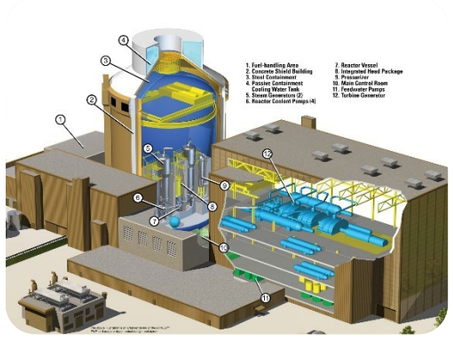


Baseline model: median value

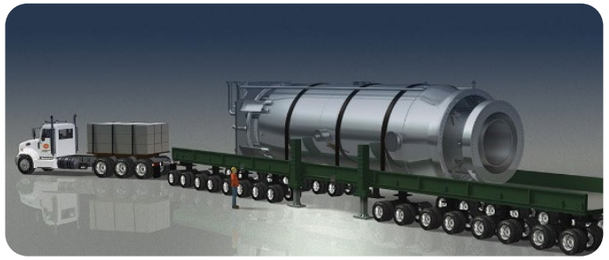
Capital Cost Estimation

Top-down Method

Existing estimates for LR



Scaling factors
Learning curves



Bottom-up Method

Materials estimates

Cost estimates

Capital Cost

Bottom Up Costing

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Special equipment	0.4
Conventional indirect	0.75
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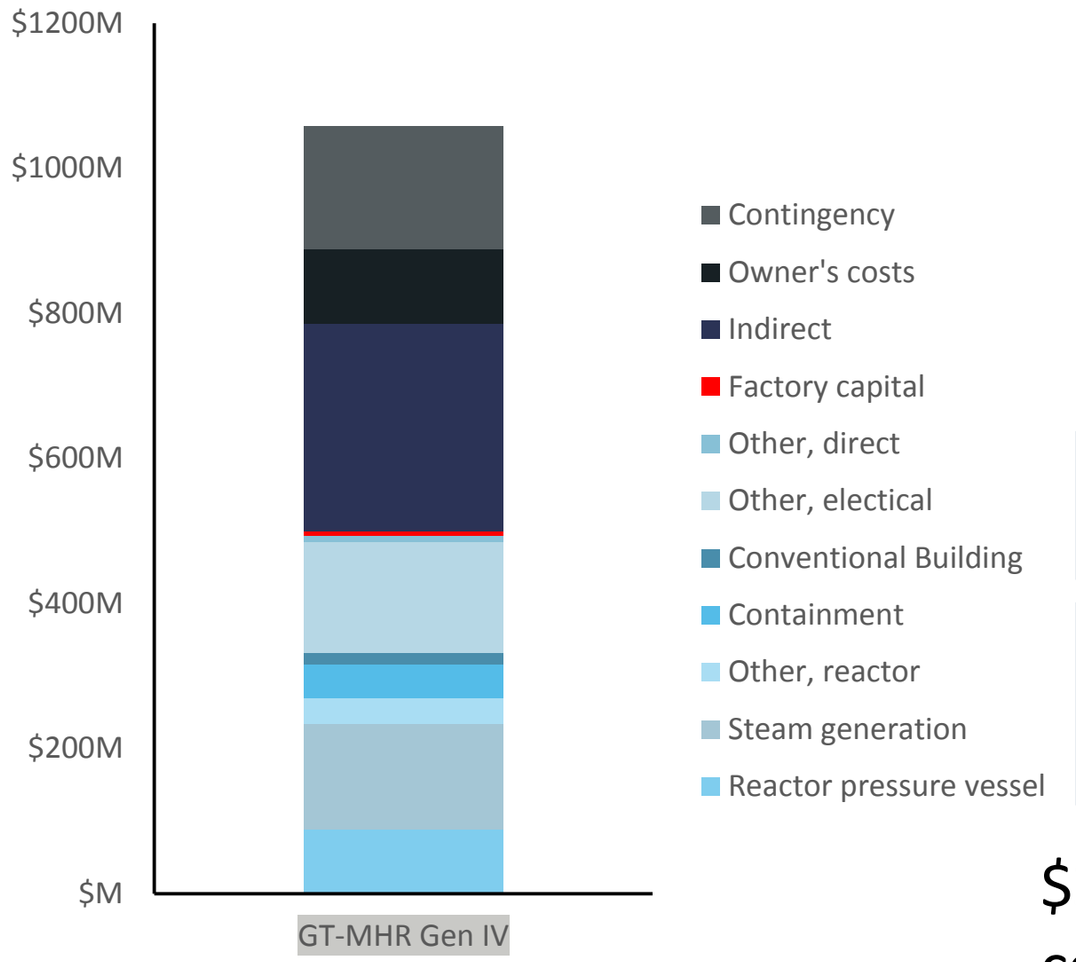
Materials: GT-MHR (helium Gen . IV)

	Structure Type	*Material Cost ($/m^3)*	*Concrete (m^3)*	*Concrete (m^3/MWe)*
Reactor pressure vessel	Substructure	252.81	18000	62.94
Steam generation	Superstructure	252.81	0	0.00
Other, reactor	Substructure	252.81	0	0.00
Containment	Superstructure	252.81	1973	6.90
Conventional building	Substructure	168.43	1586	5.55
Other, electical	Substructure	168.43	188	0.66
Other, direct	Substructure	168.43	68	0.24

Concrete (Gen IV): 76.3 m^3/MWe

Bottom up costing



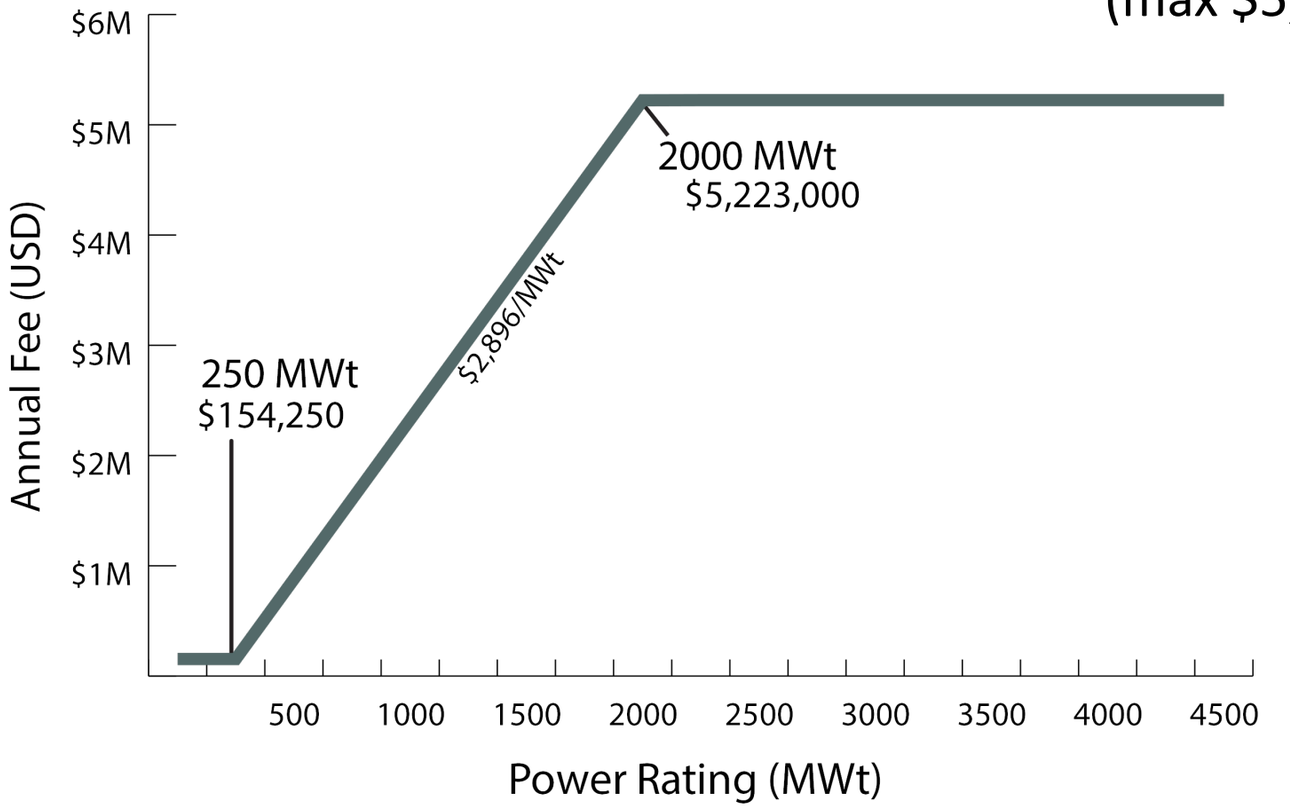
$3,697 kWe $^{-1}$ cost input

Operational Costing

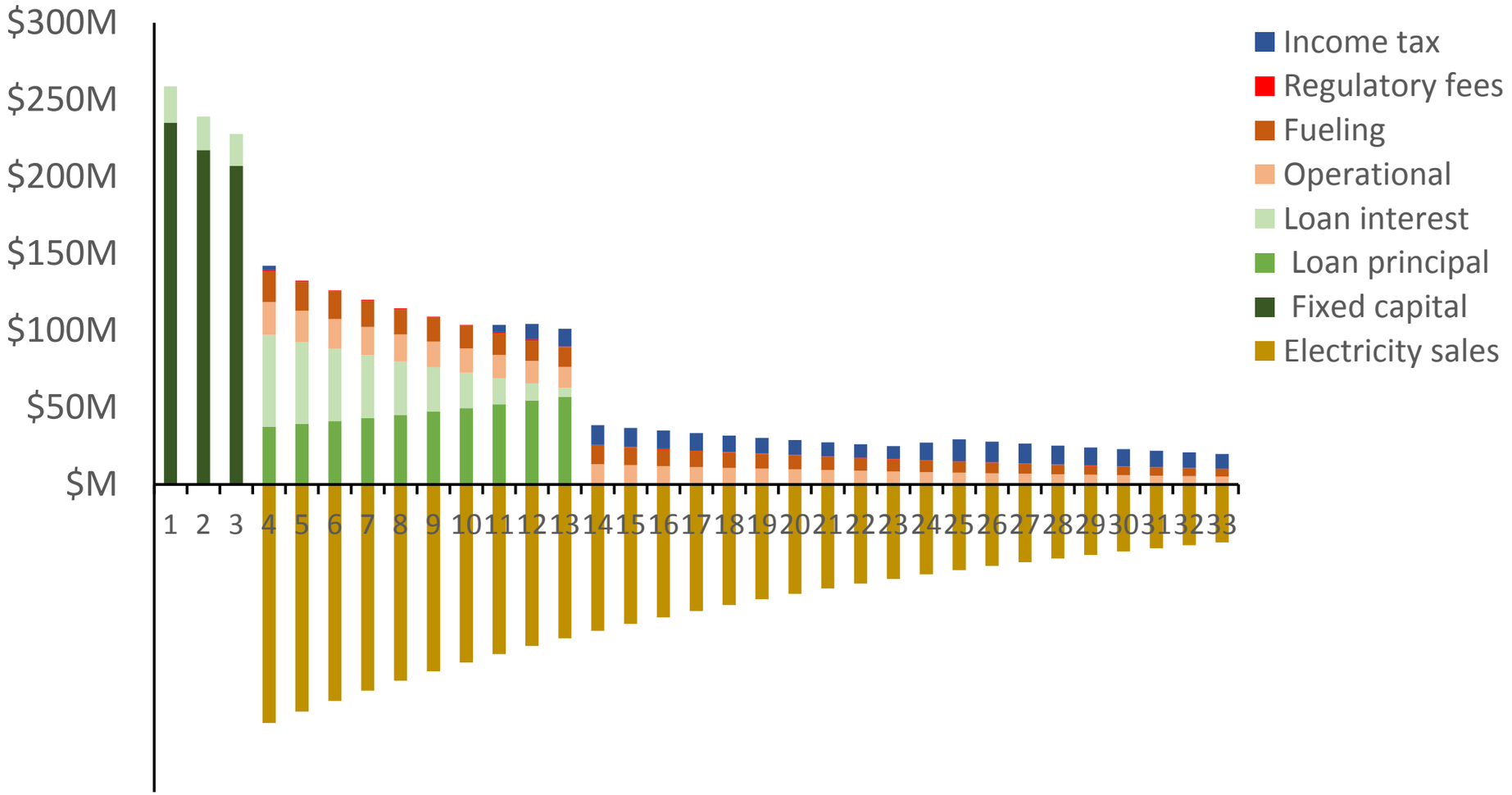
$17.38 MWh $^{-1}$

$9.10 MWh $^{-1}$
fueling

$2,896 MWt $^{-1}$
annual regulatory fee sliding scale
(max $5,223,000)

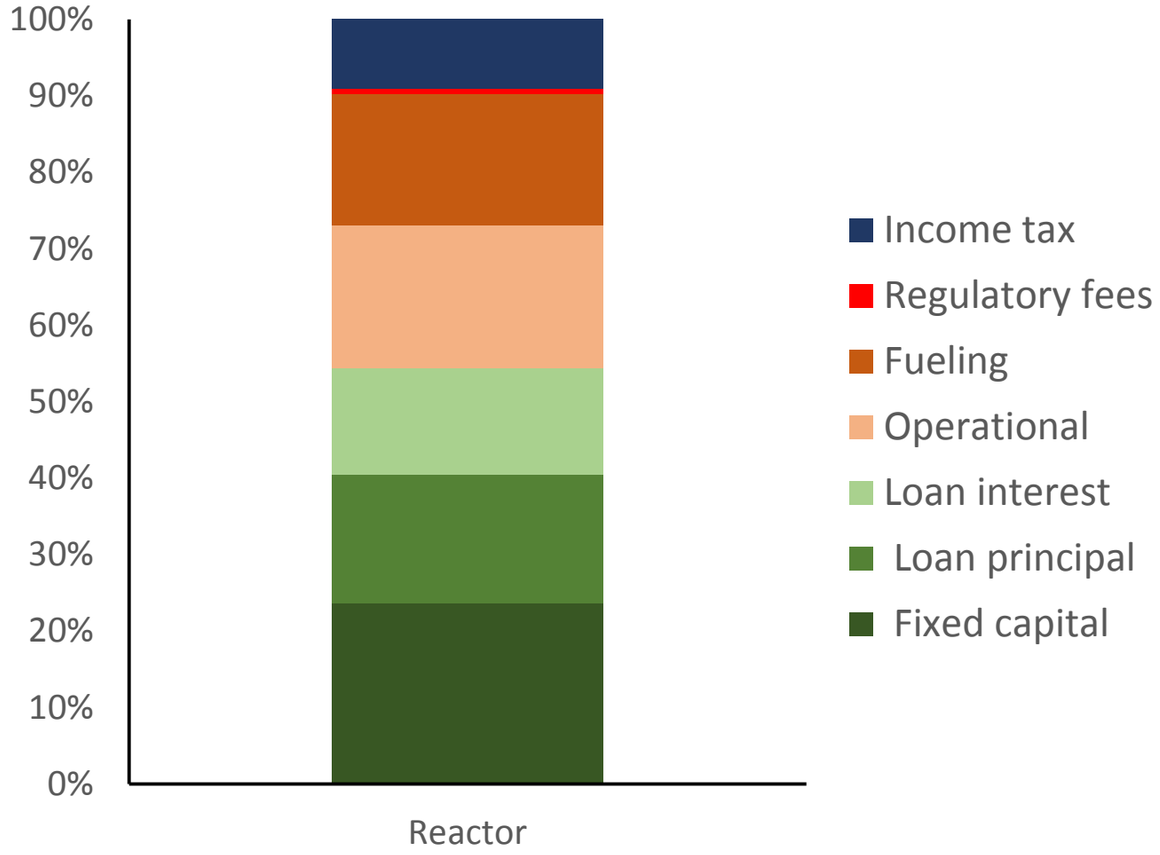


Techno-economics Analysis



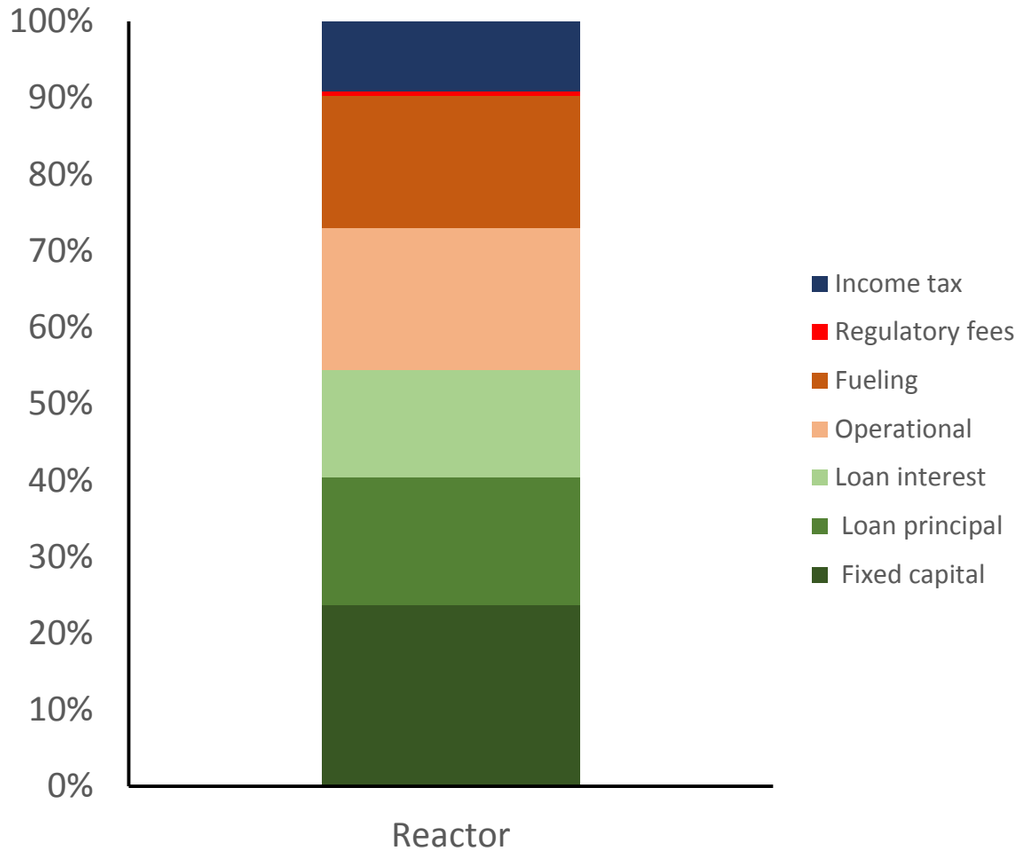
Levelized Cost of Electricity

LCOE Gen III+



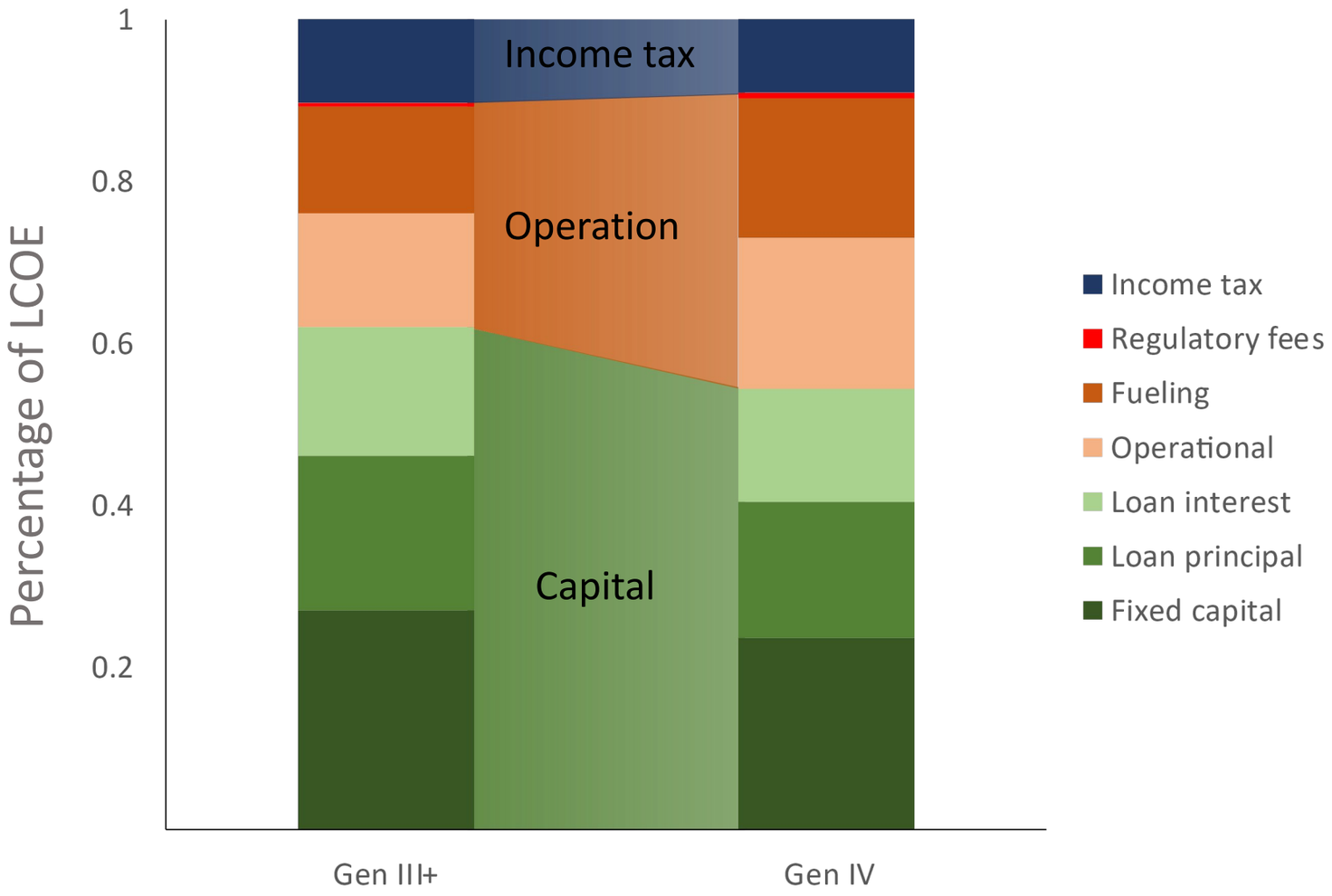
$91.80 MWh^{-1} LCOE (30 years)

LCOE Gen IV

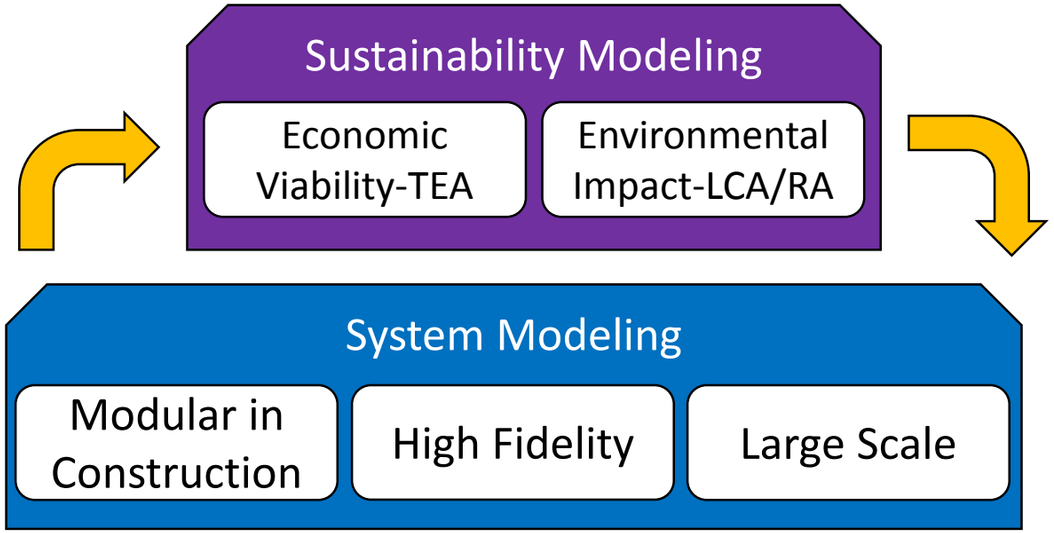


$49.43 MWh^{-1} LCOE (30 years)

Direct Comparison



The Value



- Existing modeling work in place
- Identify strategic targets based on economic metrics
- Evaluate the impact of technological changes
- Non-dilutive addition