

# Preliminary Assumptions for Natural Gas Peaking Technologies (Revisited)

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GRAC

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# At the last meeting...

- Discussed pros/cons of peaking technologies and applications in the PNW
- Reviewed overnight capital cost assumptions and normalizations
- Introduced preliminary reference plants and capital cost estimates for:
  - Frame, Aeroderivative, and Intercooled single cycle gas turbines
  - Reciprocating Engines

# Today's Discussion

- Revisit reference plants and updated capital cost estimates
- Introduce fixed and variable O&M estimates
- Introduce levelized cost estimates

# Proposed Configuration for Draft 7th Plan Reference Plants

Technology	Proposed Configuration	Capacity
Frame GT	(1) 215.8 MW GE 7F 5-series	~ 216 MW
Aeroderivative GT	(4) 47.3 MW GE LM 6000PF Sprint	~ 190MW
Intercooled/Aero Hybrid GT	(2) 100 MW GE LMS100 PB	200 MW
Reciprocating Engine	(12) 18 MW Wärtsilä	220 MW

Proposing reference plants that resemble capacity of Port Westward II (220MW) – most recent peaking plant to be constructed in the PNW

# Capital Cost Updates – New References

- California Energy Commission – DRAFT Estimated Cost of New Renewable and Fossil Generation in California (May 2014)
  - Low, Medium, High cost estimates based on survey data from projects
- NERA report on NY ISO (Aug 2013)

# Capital Cost Updates - Changes

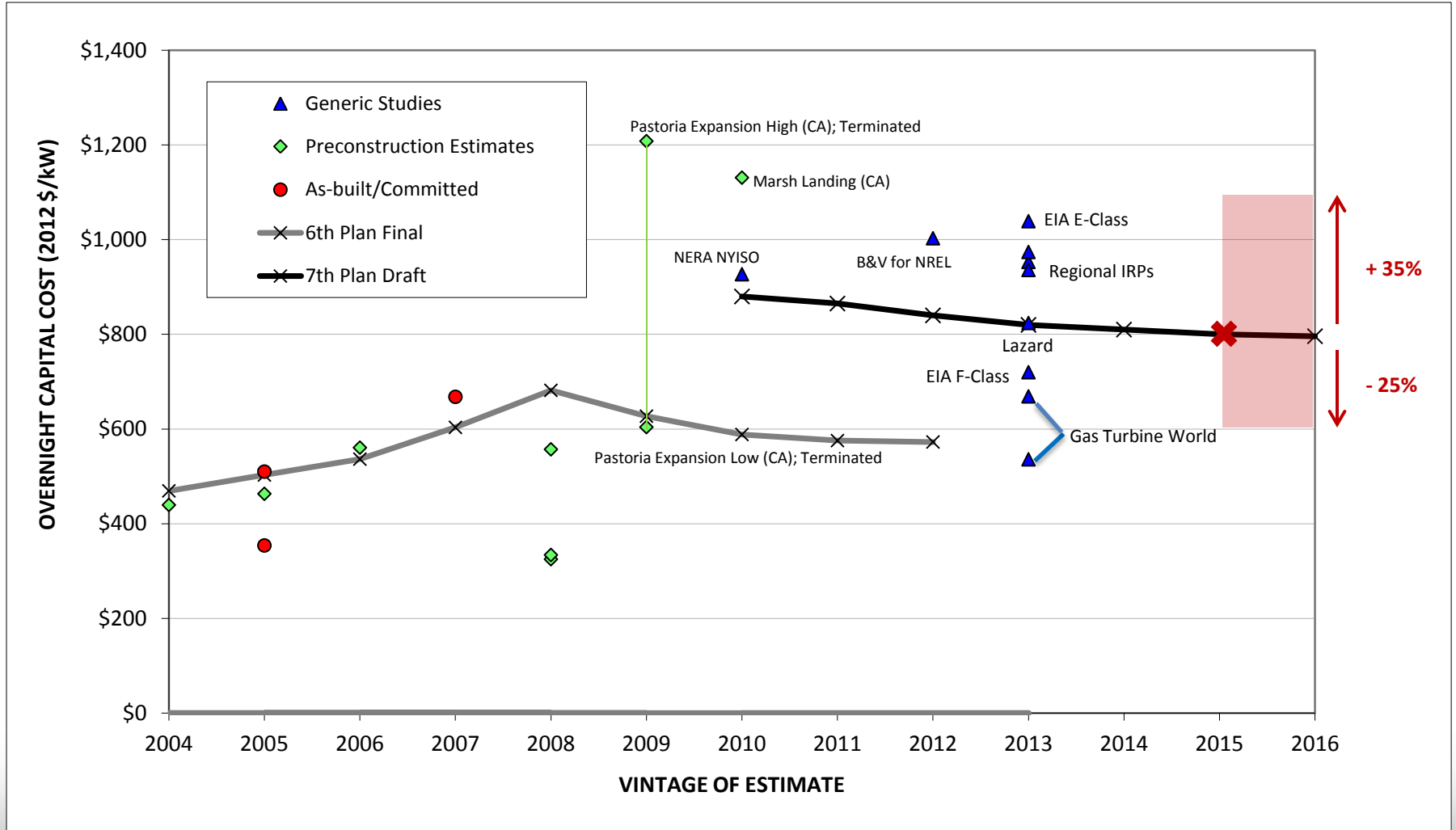
- Capital cost estimates decreased for frame, aero, intercooled from last GRAC meeting in May; Recip increased slightly
- Future is uncertain – assuming 0.5% annual cost reduction resulting from tech improvements over time
- Added – Hi/Lo bound percentage

# Preliminary Reference Plant – Frame GT

<b>Year Dollars</b>	<b>2012 \$</b>
Price Year	2015

<b>Technology &amp; Configuration base</b>	<b>(1) GE 7F 5-Series</b>
Output Total (MW)	202 MW lifecycle avg
Heat Rate (btu/kWh)	9801 HHV
Availability	91%
Capacity Factor	TBD based on discussion, location
Economic Life (Years)	30
Construction Lead Time (Months)	18 planning & development 15 construction (33 months total, ~2.75 years)

# Preliminary Draft 7P Capital Cost Estimate for Frame GT





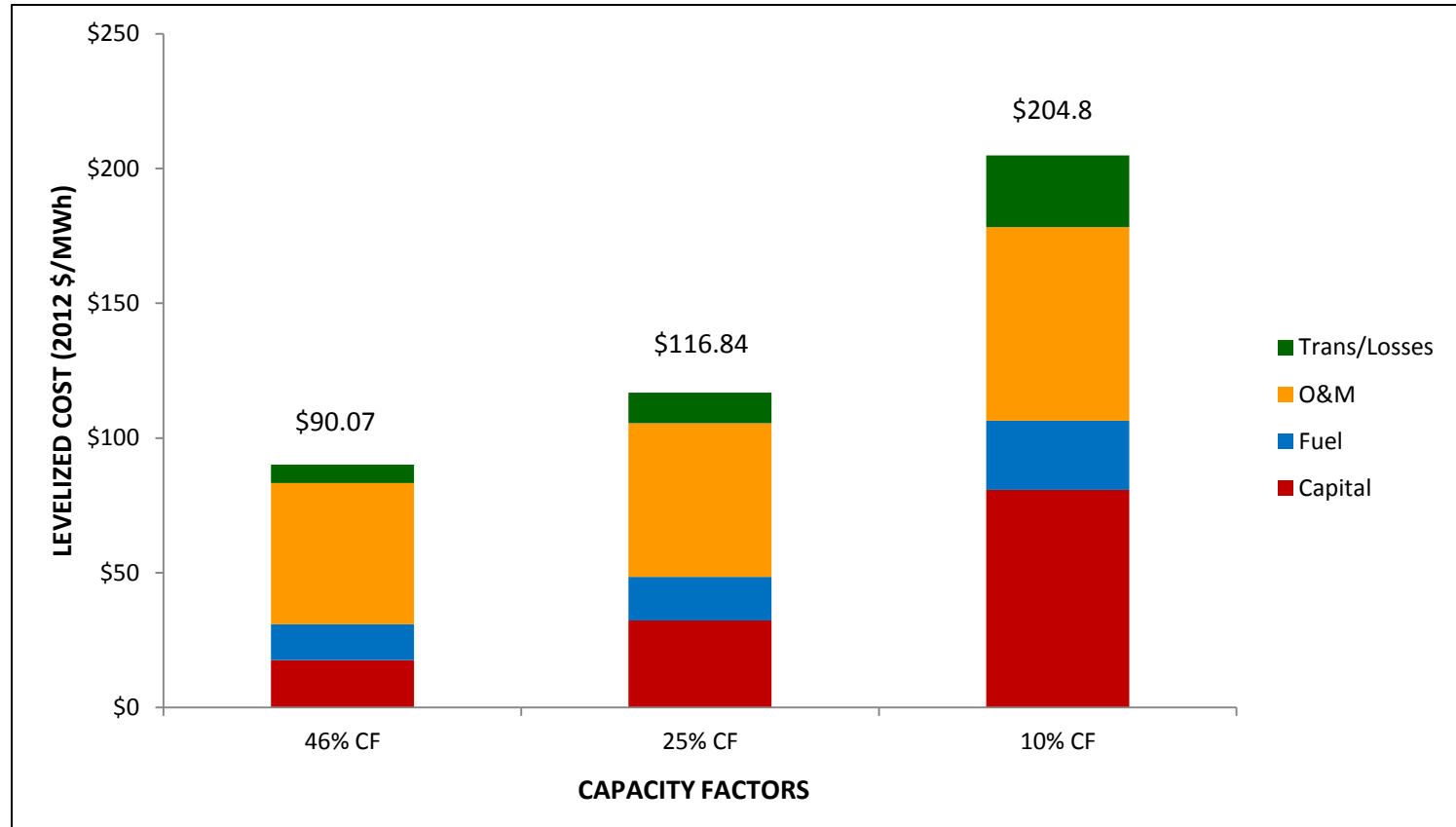
# Preliminary Reference Plant – Frame GT (2)

Year Dollars	2012 \$
Price Year	2015

Capital Cost (MM)	\$161.6MM (lifecycle)
Capital Cost (\$/kW)	\$800 (lifecycle)
Hi Bound (\$/kW)	\$1,080 (35% above)
Lo Bound (\$/kW)	\$600 (25% below)
Capital Cost Escalation	-0.5% annual after 2015

Fixed O&M	\$7.00 ( <i>Sixth Plan \$10.20</i> )
Variable O&M	\$10.00 ( <i>Sixth Plan \$1.10</i> )

# Preliminary Levelized Cost – Frame GT



## Assumptions:

- Council's 2013 Medium Natural Gas Price Forecast – PNW East
- No emission cost added at this time; pending environmental methodology
- IOU financing, 2012\$, 2015 Operation

# Preliminary Reference Plant – Aeroderivative GT (1)

Year Dollars

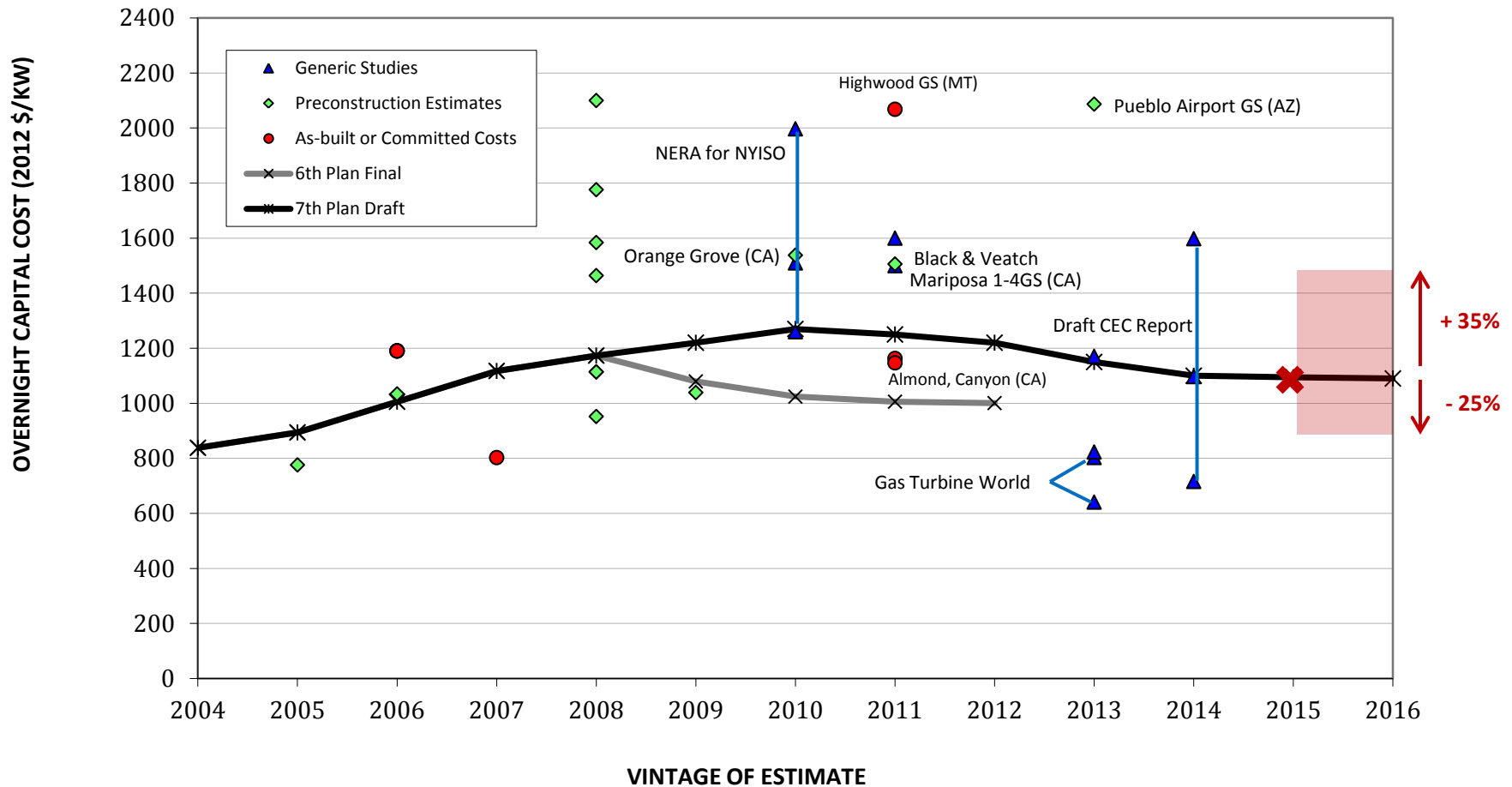
2012 \$

Price Year

2015

<b>Technology &amp; Configuration base</b>	<b>(4) GE LM6000 PF SPRINT</b>
Output Total (MW)	180 MW lifecycle avg
Heat Rate (btu/kWh)	9048 HHV
Availability	91%
Capacity Factor	TBD based on discussion, location
Economic Life (Years)	30
Construction Lead Time (Months)	18 planning & development 15 construction (33 months total, ~2.75 years)

# Preliminary Draft 7P Capital Cost Estimate for Aeroderivative GT



# Preliminary Reference Plant – Aeroderivative GT (2)

Year Dollars

2012 \$

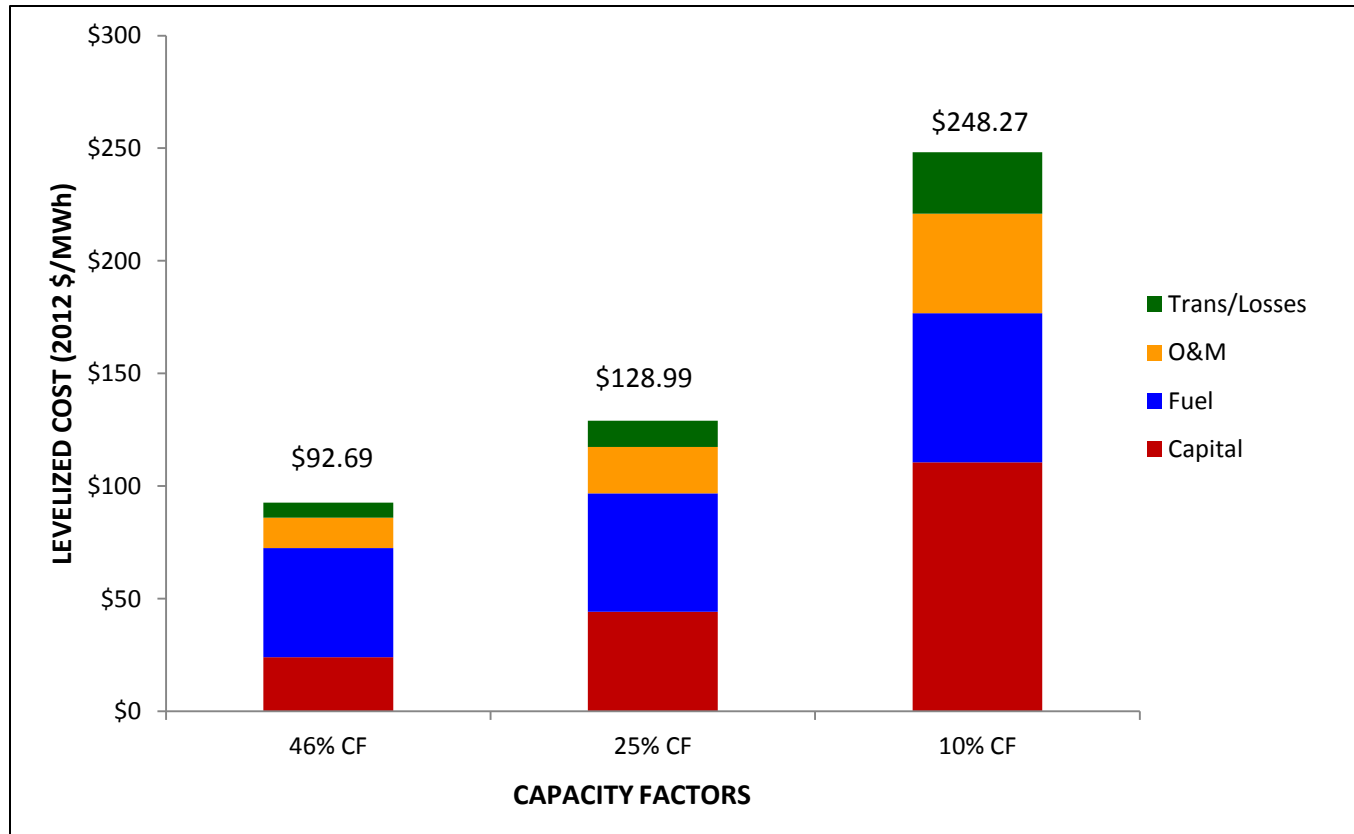
Price Year

2015

Capital Cost (MM)	\$198MM (lifecycle)
Capital Cost (\$/kW)	\$1,100 (lifecycle)
Hi Bound (\$/kW)	\$1,485 (35% above)
Lo Bound (\$/kW)	\$825 (25% below)
Capital Cost Escalation	-0.5% annual after 2015

Fixed O&M	\$25.00 ( <i>Sixth Plan \$12.20</i> )
Variable O&M	\$5.00 ( <i>Sixth Plan \$4.50</i> )

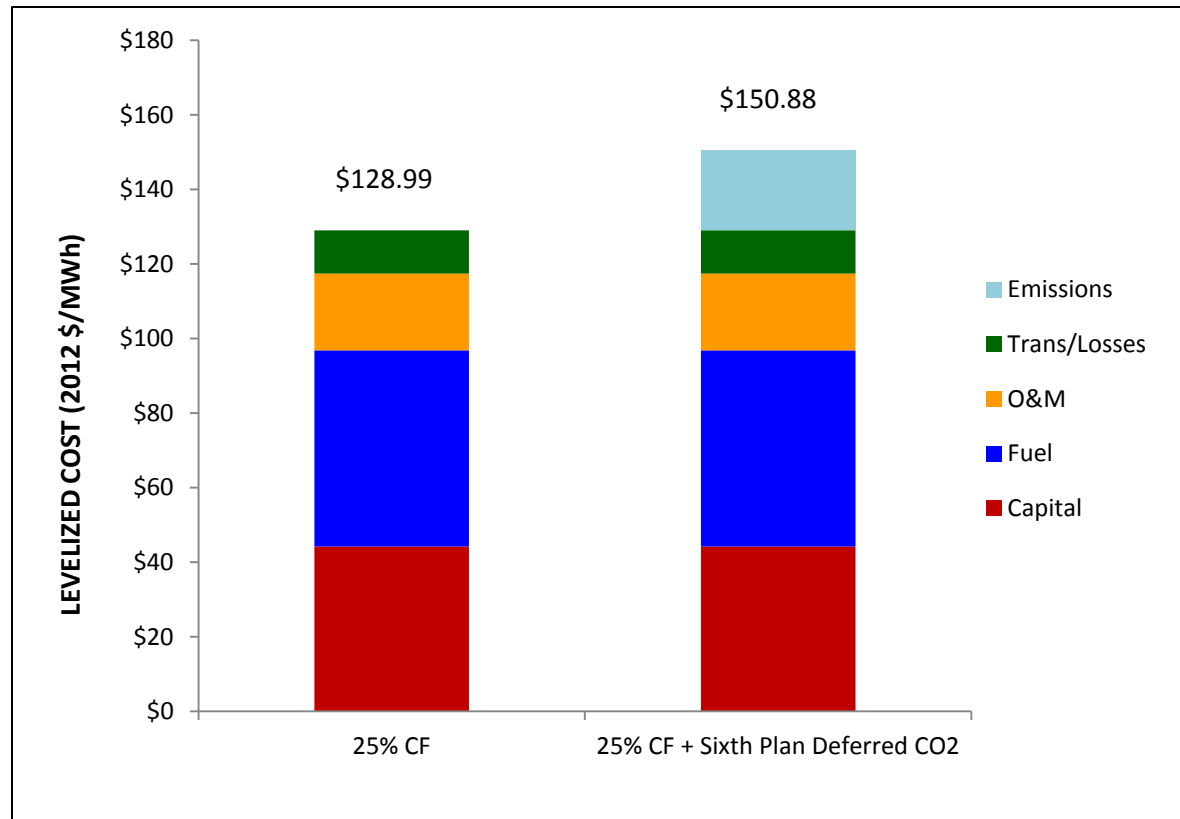
# Preliminary Levelized Cost – Aeroderivative GT (1)



## Assumptions:

- Council's 2013 Medium Natural Gas Price Forecast – PNW East
- No emission cost added at this time; pending environmental methodology
- IOU financing, 2012\$, 2015 Operation

# Preliminary Levelized Cost – Aeroderivative GT (2)



## Assumptions:

- Sixth Power Plan CO2 Price Forecast, \$2012, Deferred start to 2015
- Council's 2013 Medium Natural Gas Price Forecast – PNW East
- IOU financing , 25% Capacity Factor, 2012\$, 2015 Operation

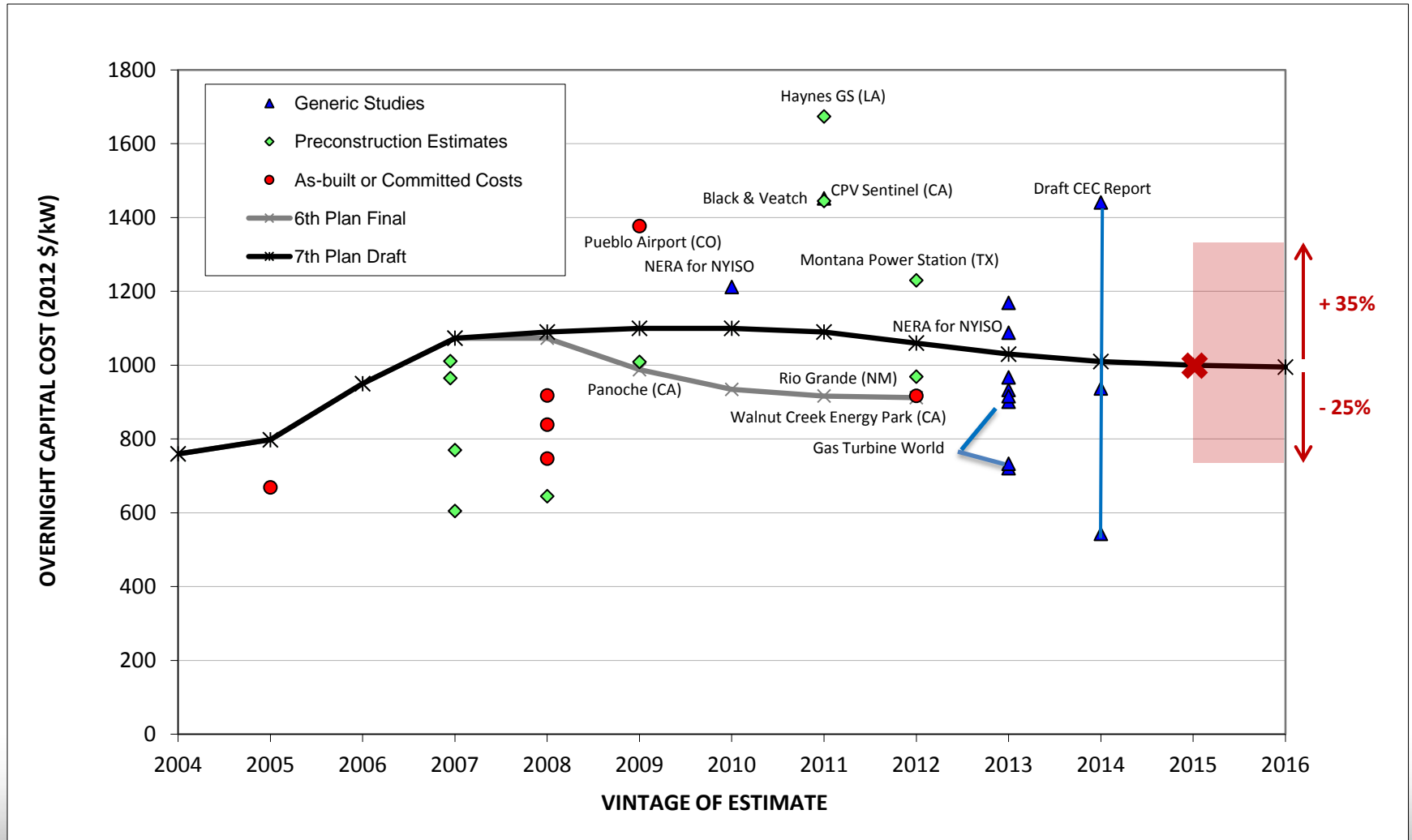
# Preliminary Reference Plant – Intercooled GT

<b>Year Dollars</b>	<b>2012 \$</b>
Price Year	2015

<b>Technology &amp; Configuration base</b>	<b>(2) GE LMS100PB</b>
Output Total (MW)	187 MW lifecycle avg
Heat Rate (btu/kWh)	8541 HHV
Availability	91%
Capacity Factor	TBD based on discussion, location
Economic Life (Years)	30
Construction Lead Time (Months)	18 planning & development 15 construction (33 months total, ~2.75 years)



# Preliminary Draft 7P Capital Cost Estimate for Intercooled GT



# Preliminary Reference Plant – Intercooled GT (2)

Year Dollars

2012 \$

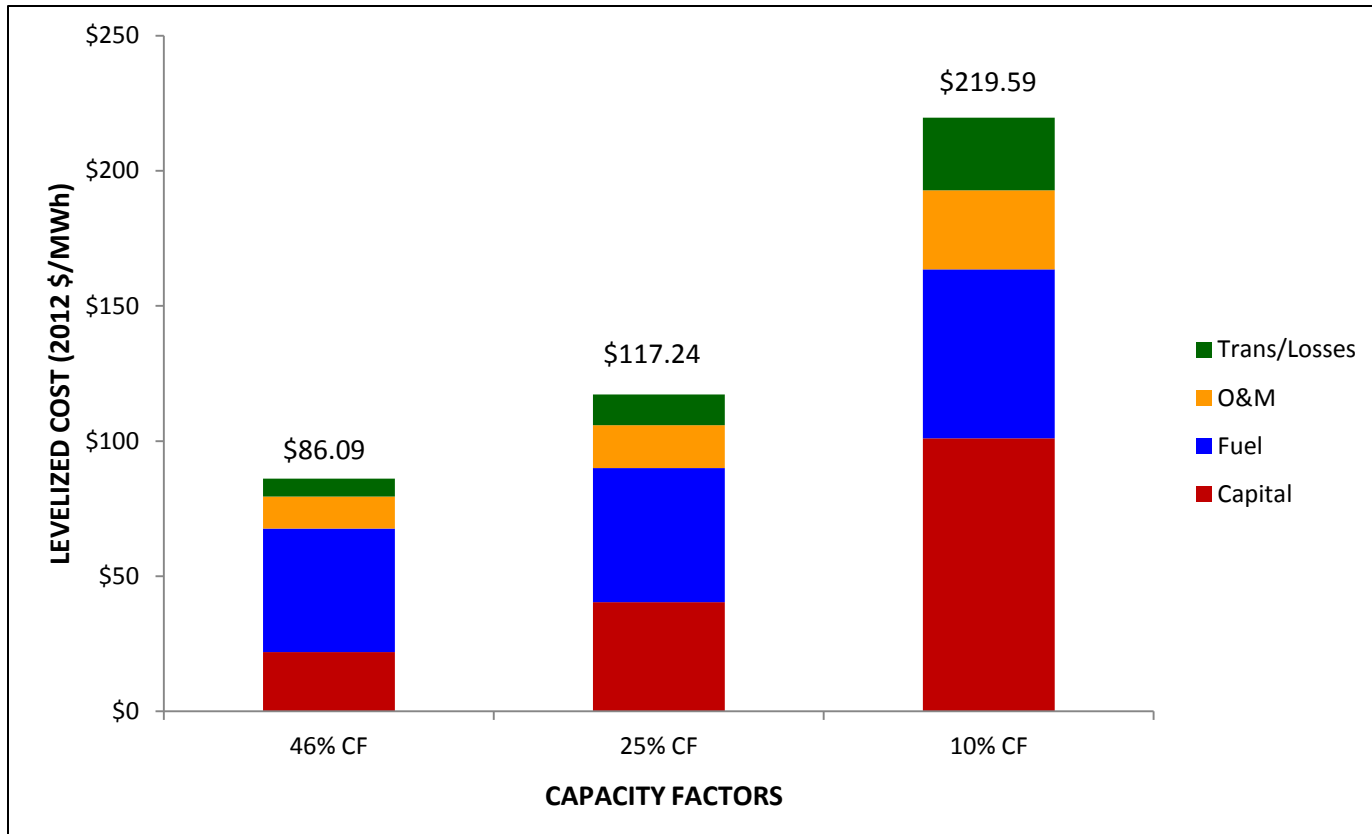
Price Year

2015

Capital Cost (MM)	\$187MM (lifecycle)
Capital Cost (\$/kW)	\$1,000 (lifecycle)
Hi Bound (\$/kW)	\$1,350 (35% above)
Lo Bound (\$/kW)	\$750 (25% below)
Capital Cost Escalation	-0.5% annual after 2015

Fixed O&M	\$11.00 ( <i>Sixth Plan \$7.50</i> )
Variable O&M	\$7.00 ( <i>Sixth Plan \$5.60</i> )

# Preliminary Levelized Cost – Intercooled GT



**Assumptions:**

- Council's 2013 Medium Natural Gas Price Forecast – PNW East
- No emission cost added at this time; pending environmental methodology
- IOU financing, 2012\$, 2015 Operation

# Reciprocating Engines

1. Capital Cost Estimate
2. O&M Estimate
3. Reference Plant
4. Levelized Cost of Energy

# Reciprocating Engines for Electric Power Generation

Recips are internal combustion engines – an air/fuel(Ntrl Gas) mixture is compressed by a piston and ignited within a cylinder to drive a piston and turn the shaft.

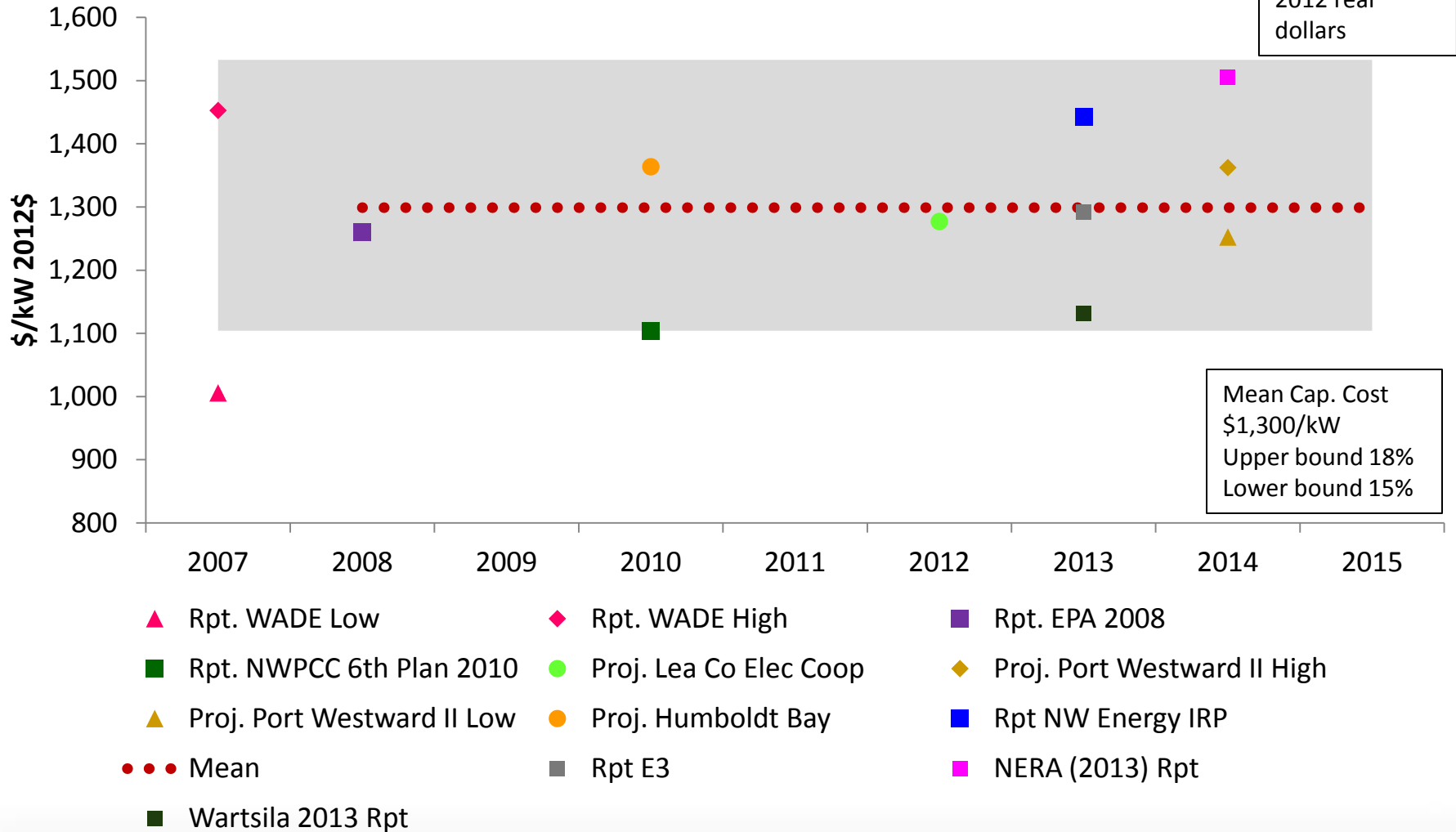
These engines can burn a variety of fuels including natural gas, fuel oil and biofuels.

Often individual engines are grouped into blocks called generating sets.

## Strengths

1. Start quickly
2. Follow load well
3. Have good part-load efficiencies
4. Maintain output at increasing elevation
5. Good reliability
6. Minimal water usage

# Normalized Capital Costs for Reciprocating Engine Technologies with High and Low Band



# Capital Cost Sources

	Projects	Reports/Other
1	Port Westward II – Clatskanie, Oregon	
2	Lea Co. Electric Coop – Lovington, New Mexico	
3	Humboldt Bay – Eureka, California	
4		NW Power and Conservation Council 6 <sup>th</sup> Plan
5		EPA 2008 Tech. Char. Recip. Engines, by E3
6		World Alliance for Decentralized Energy (WADE)
7		Northwestern Energy 2013 Elec. Supply Res. Proc. IRP
8		E3 2014
9		NERA 2013
10		Wärtsilä 2013

# Preliminary Reference Plant – Gas-Fired Reciprocating Engine

Year Dollars

2012 \$

Price Year

2015

<b>Technology &amp; Configuration base</b>	
Output Total (MW)	220 MW (Lifecycle)
Heat Rate (btu/kWh)	8,370
Availability	91%
Capacity Factor	TBD based on discussion, location
Economic Life (Years)	30
Development Time (months)	18
Construction Time (months)	15



# Preliminary Reference Plant – Gas-Fired Reciprocating Engine

Year Dollars

2012 \$

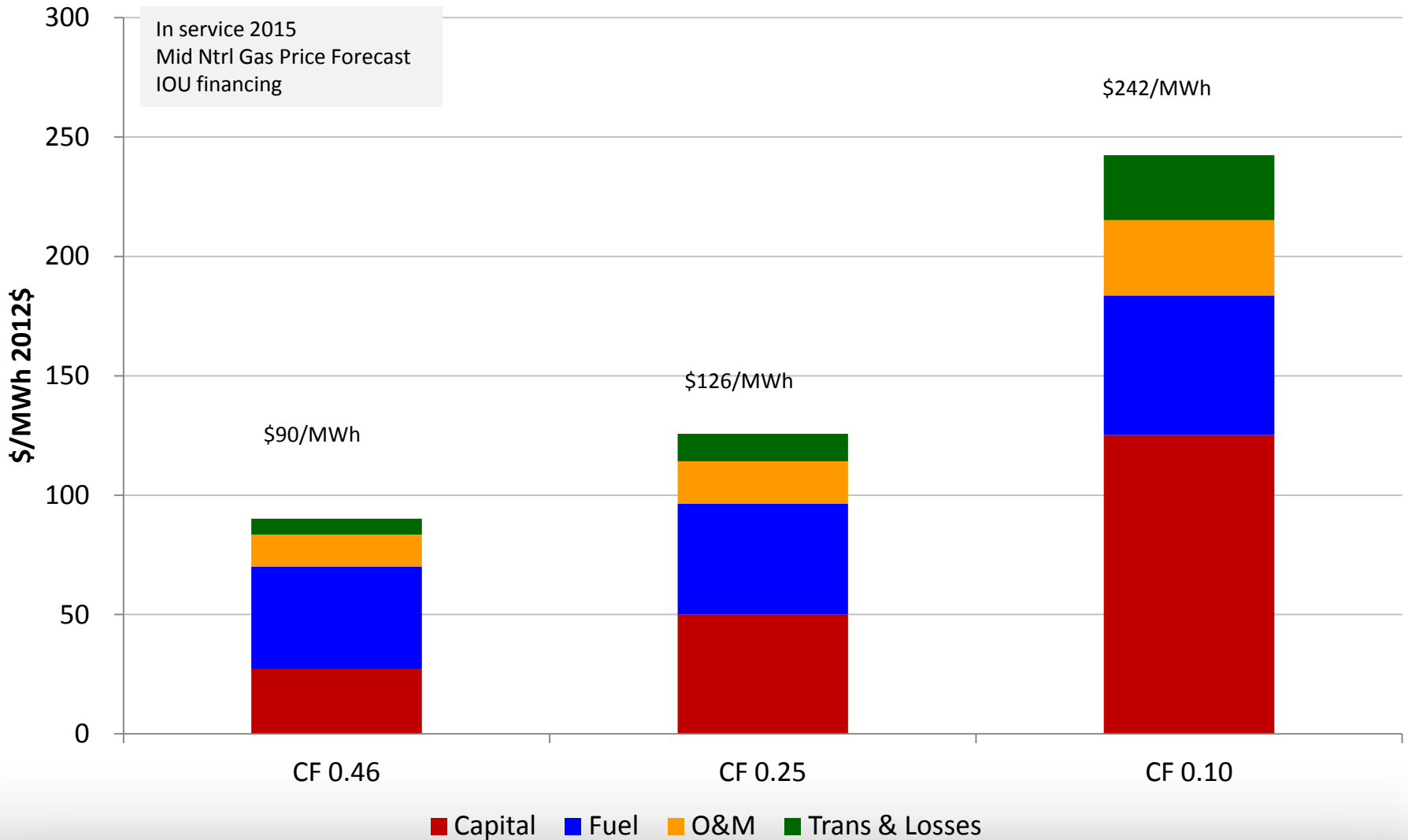
Price Year

2015

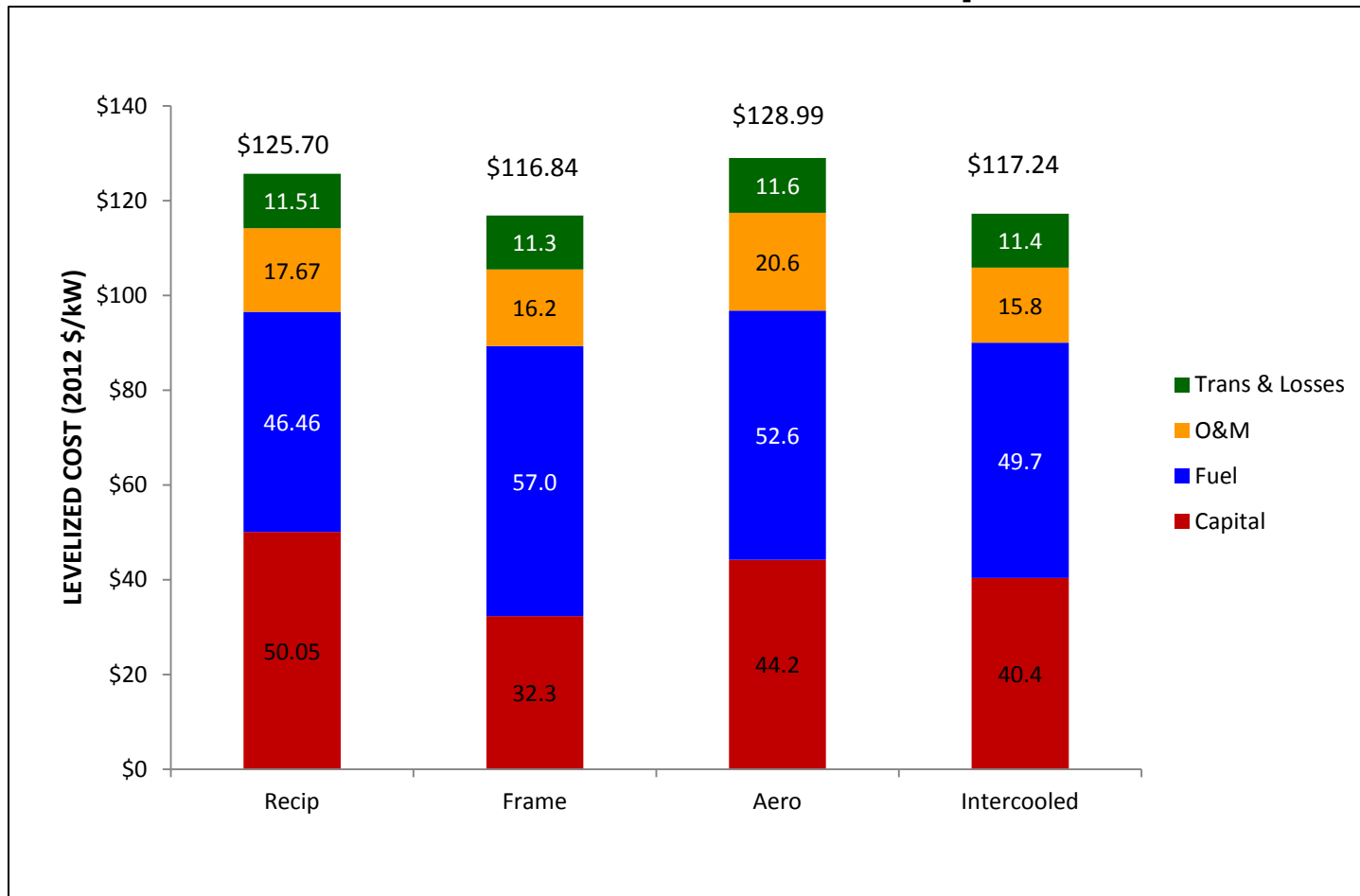
Capital Cost (MM)	\$286 MM (lifecycle)
Capital Cost (\$/kW)	\$1,300(lifecycle)
Hi Bound (\$/kW)	\$1,533 (18% above)
Lo Bound (\$/kW)	\$1,104 (15% below)
Capital Cost Escalation	-0.5% annual after 2015

Fixed O&M (\$/kw-yr)	\$10.00 ( <i>Sixth Plan \$12.30</i> )
Variable O&M (\$/MWh)	\$9.00 ( <i>Sixth Plan \$0.00</i> )

# Reciprocating Engine - Levelized Cost of Energy by Capacity Factor



# Gas Peaker Comparison



## Assumptions:

- Council's 2013 Medium Natural Gas Price Forecast – PNW East
- No emission cost added at this time; pending environmental methodology
- IOU financing , 2012\$, 2015 Operation, 25% Capacity Factor

# Next Steps

- Refine estimates as necessary, based on feedback today
- Once environmental methodology is developed for draft plan, incorporate into estimates