Preliminary Assumptions for Natural Gas Peaking Technologies

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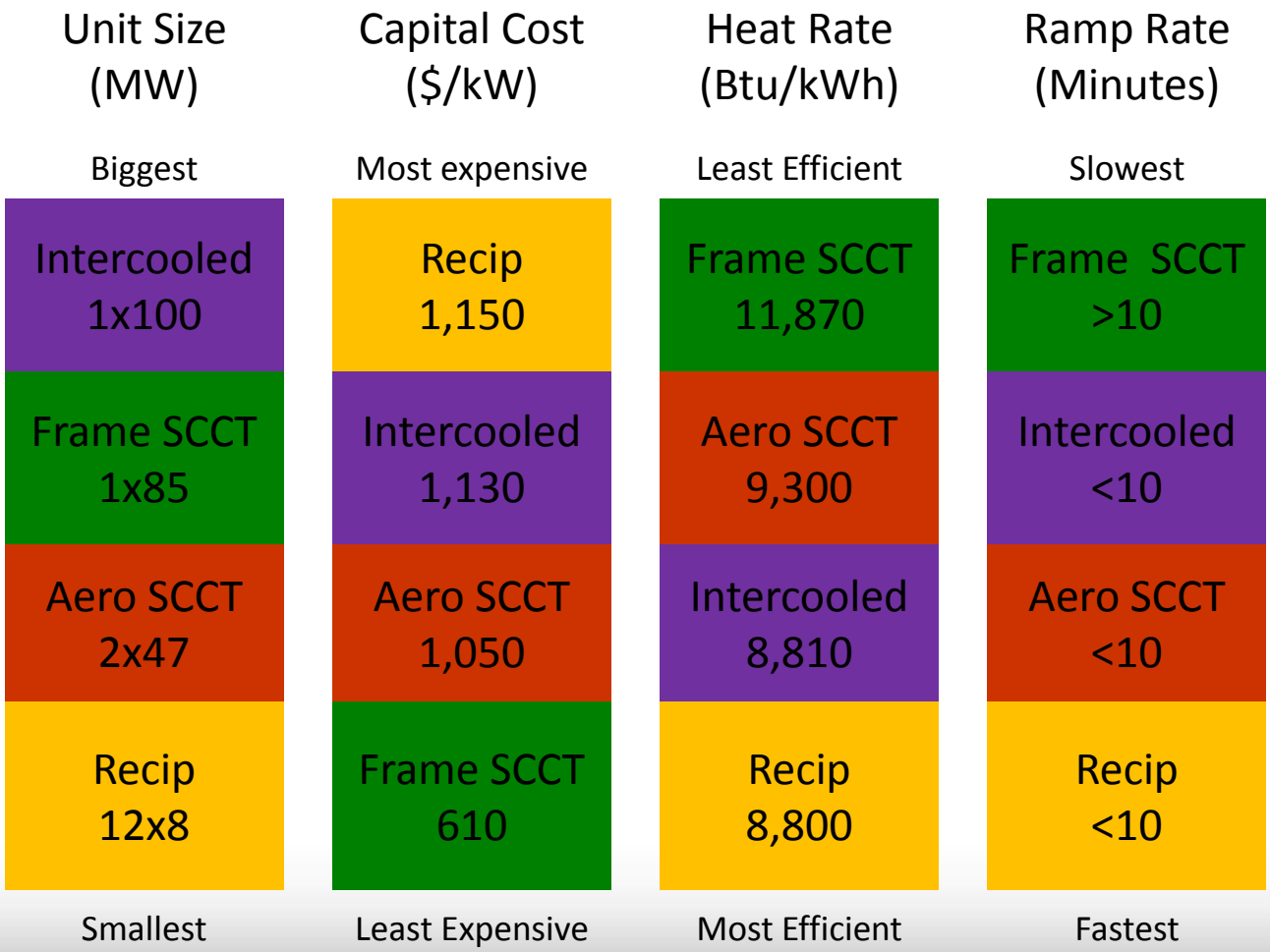
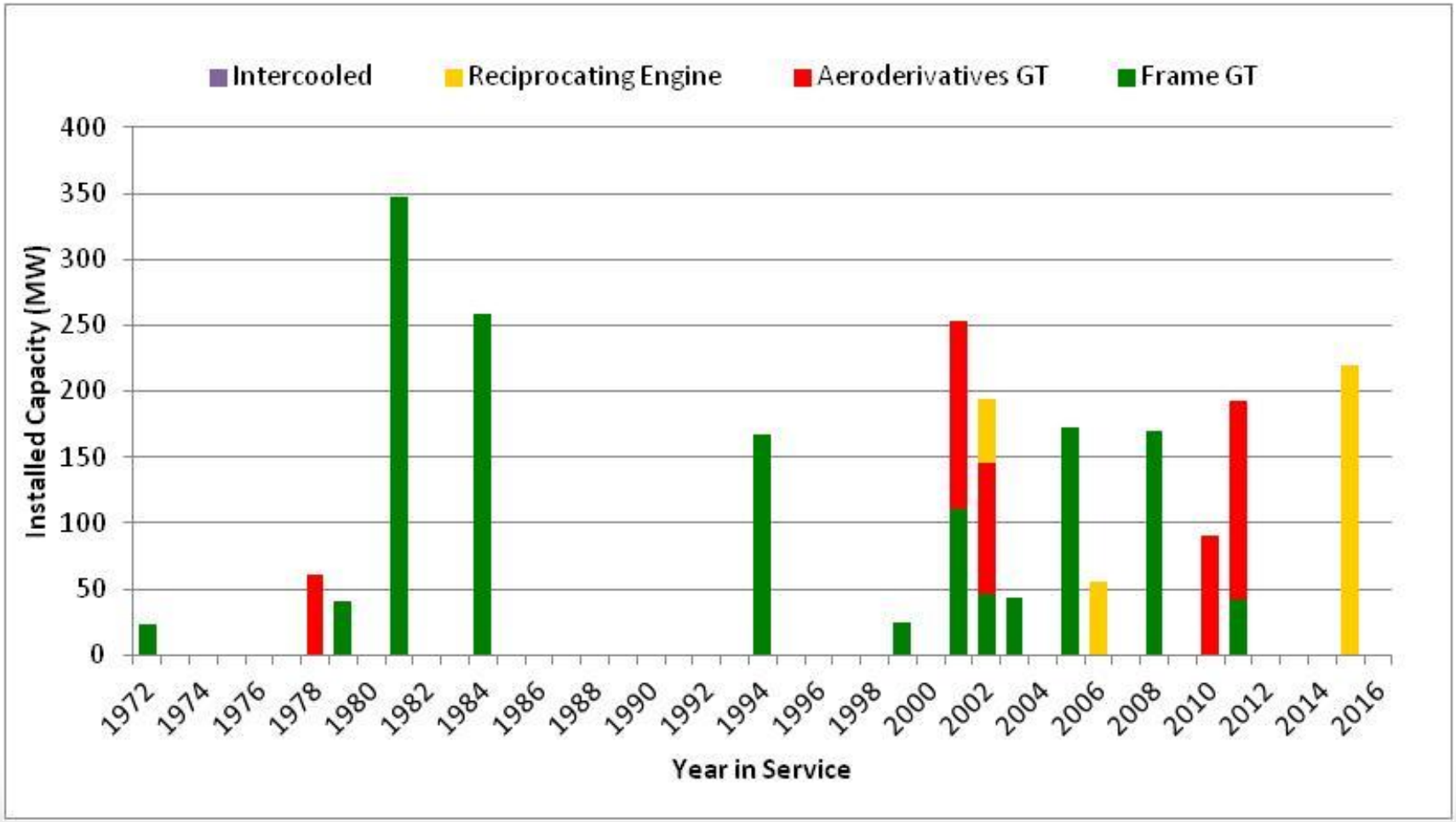
Today's Discussion

- Aeroderivative Gas Turbine Technology
  - Proposed reference plant and assumptions
  - Preliminary cost data
- Pursue both Frame and Intercooled/Aero Hybrid technologies as well?
  - Proposed reference plant configuration
- Reciprocating Engine
  - Preliminary discussion on technology with Wärtsilä representative John Robbins

Peaking Power Plant Characteristics
6th Power Plan ($2006)



Historical Peaking Plant Additions in the Region (MW)



Note: There are currently no intercooled/aero hybrid plants in the PNW

Utility IRPs – Peaking Plants Analyzed

IRP/Plan	Frame	Aero	Intercooled/ Aero Hybrid	Recip
Avista	GE 7EA	P&W FT8 Twin-pac	GE LMS 100	Wartsila 18V34
Idaho Power	X	X		
NorthWestern	GE 7EA	P&W FT8 Twin-pac LM 6000		Caterpillar G16CM34
PacifiCorp	GE 7F5	GE LM 6000PG	GE LMS 100	Wartsila 18V50SG
PGE		X		X
PSE	X	X		X
Sixth Power Plan	GE 7EA	GE LM 6000PC Sprint	GE LMS100PB	X

Proposed Configuration for Reference Peaking Plants

Technology	Proposed Configuration	Capacity
Aeroderivative GT	(4) 47.3 MW LM 6000PF Sprint	~ 190MW
Frame GT	(2) 85 MW GE 7E	170 MW
Intercooled/Aero Hybrid GT	(2) 100 MW LMS 100	200 MW
Reciprocating Engine	(12) 18 MW Wärtsilä	220 MW

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

Existing Aeroderivative Gas Plants in the Region

Project	In Service	Technology	Capacity	Location	Load
Fredonia 3 and 4	July 2001	(2) P&W FT8 Twin-pac	108 MW (base load rating)	Mount Vernon, WA	PSE
Klamath Generation Peakers	June 2002	(2) 54 MW P&W FT8 Twin-pac	95 MW	Klamath, OR	IPP; winter-only PPA w/ PSE
Dave Gates Generating Station	Jan 2011	(3) P&W SWIFTPAC	150 MW	Anaconda, MT	NorthWestern
Highwood Generating Station	Sept 2011	(1) GE LM6000PF GT	45 MW	Cascade, MT	Southern MT G&T resource

Recent Aero Gas Plants in WECC

Project	In Service	Technology	Capacity	Location	Overnight Capital Cost (2012$)*
Almond 2-4	July 2012	(3) 58 MW GE LM6000 PG	174 MW	Turlock, CA	$1,153/kw
Canyon Power Plant 1-4	March 2012	(4) 50 MW GE LM6000PC Sprint	200 MW	Anaheim, CA	$1,137/kw
Mariposa 1-4	Oct 2012	(4) GE LM6000PC Sprint	200 MW	Tracy, CA	$1,254/kw
Orange Grove	June 2010	(2) GE LM6000PC Sprint	99 MW	Pala, CA	$1,431/kw

- Predominantly GE LM6000 products, with a few P&W FT8 twin pacs
- *ISO; adjusted to 2012$, state construction cost index, vintage of cost estimate, scope of estimate to extent info is available (e.g. add owner's cost if necessary)

Proposed Aeroderivative Reference Plant (1)

- **LM6000-PF gas turbine**
  - Popular choice among new installs in WECC
  - More available information on cost and performance
  - Second of three LM6000 generations
    - Same gen as LM6000PD used in Sixth Plan, but with improved NOx emissions reductions
  - Available starting in 2007
  - 42 – 47MW output (w/ SPRINT)
  - 5-minute fast start, 10-minute full power
  - Advanced emissions technology
    - Reduced NOx emissions to 15 ppm
- Pratt & Whitney Twin-Pac??
  - In recent years, P&W plants constructed in PNW

Proposed Aeroderivative Reference Plant (2)

Model:	GE LM6000PF SPRINT
Configuration:	(4) 47.3 MW (nominal) GTGs
Nominal heat rate (Btu/kwh):	8,170 (LHV) / 9,070 (HHV)
Site Capacity (ISO conditions):	183 MW ("new and clean") **179 MW** lifecycle
Site heat rate (Btu/kwh):	9,350 ("new and clean") **9,430** lifecycle (36% efficiency)
Location:	Pick a representative site for each AURORA LRA and apply elevation adjustment curve
Economic Life:	30 years

* All SCCT reference plants to match Port Westward II – 220 MW

Other Assumption Parameters (1)

Availability Parameters	Aeroderivative Engine
Scheduled maintenance outages	14 days/yr
Equivalent forced outage rate	5%
Mean time to repair	88 hours
Equivalent annual availability	91%

Unit Commitment Parameters	Aeroderivative Engine
Minimum load	25%
Minimum run time	1 hour
Minimum down time	1 hour
Ramp rate	Cold start to full in 10 mins

Note: These assumptions are from the Council's Sixth Power Plan. Are they still reasonable?

Other Assumption Parameters (2)

Development and Construction Schedule	Aeroderivative Engine
Development Site acquisition, permitting, prelim engineering, interconnection agreement	18 months, 5% total plant cost
Early Construction Final engineering, eqmt order, site prep, interconnection, instrastructure construction	9 months, 50% of total plant cost
Committed Construction Major eqmt installation, commissioning	6 months, 45% of total plant cost
Total:	**33 months (2.75 years)**

Note: These assumptions are from the Council's Sixth Power Plan. Are they still reasonable?

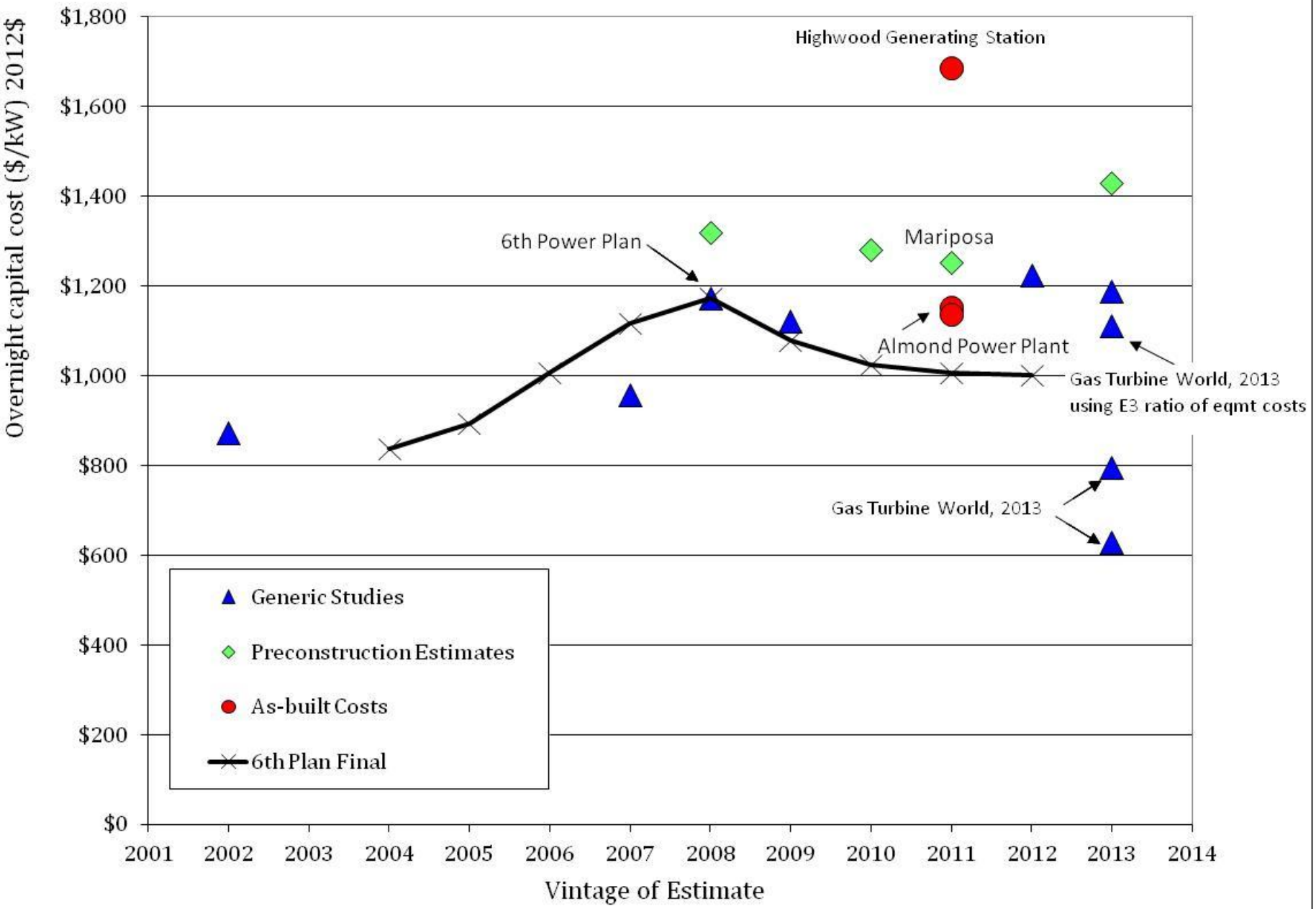
Other Assumption Parameters (3)

Operating and Maintenance Costs	Aeroderivative Engine
Fixed O&M	$13/kW/yr
Variable O&M	$4/MWh
Fixed and Variable Fuel Costs	Price forecast series (2015-35) 2014 Fixed Med PNWW = $21.13/kw/yr 2014 Var Med PNWW = $3.74/MMbtu
Decommissioning Cost	Salvage value offsets decommissioning cost
Interim Capital Investments (financed)	Roll into fixed O&M

Note: These assumptions are from the Council's Sixth Power Plan. Are they still reasonable? Particularly the Fixed and Variable O&M.

Preliminary Cost Estimates

- Sixth Power Plan, NW Utility IRPs
- Energy and Environmental Economics, Inc. (E3) – Cost and Performance Review of Generation Technologies (October 2012)
- Gas Turbine World Handbook (2013)
- California Energy Commission – Cost of Generation (2010)
- Various WECC plants and cost data


Overnight capital cost ($/kW) 2012$
$1,800
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Vintage of Estimate
Highwood Generating Station
6th Power Plan
Mariposa
Almond Power Plant
Gas Turbine World, 2013
using E3 ratio of eqmt costs
Gas Turbine World, 2013
Generic Studies
Preconstruction Estimates
As-built Costs
6th Plan Final

Next Steps - Aeroderivatives

- Finish collecting cost data and finalize capital, O&M costs and 20-year forecast
- Finalize reference plant
- Present revised assumptions at future GRAC meeting
- Add emissions characteristics

Next Steps – Frame, Intercooled/Aero Hybrid, Recips

- Collect cost and technology data
  - 20 year forecast
- Propose reference plants
- Present preliminary assumptions to future GRAC meeting
- Add emissions characteristics

Acronyms

Acronym	
GTG	Gas turbine generator
DLN	Dry low NOx (nitrogen oxide)
CO	Carbon monoxide
VOC	Volatile organic compounds (e.g. methane)
SCR	Selective catalytic reduction
Oxy Cats	Oxidation catalysts
ISO	International Standards Organization
STP	Standard Temperature and Pressure – 59F, 1atm
LRA	Aurora Load Resource Area