330 kWe Packaged CHP System with Reduced Emissions

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Cummins Power Generation/Cummins Engine Business Unit of Cummins, Inc.

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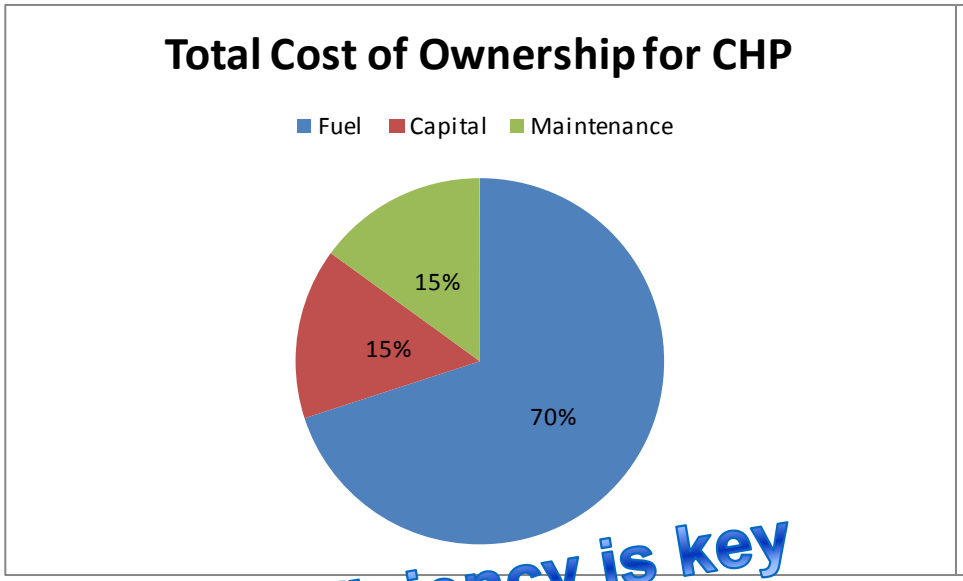
Executive Summary

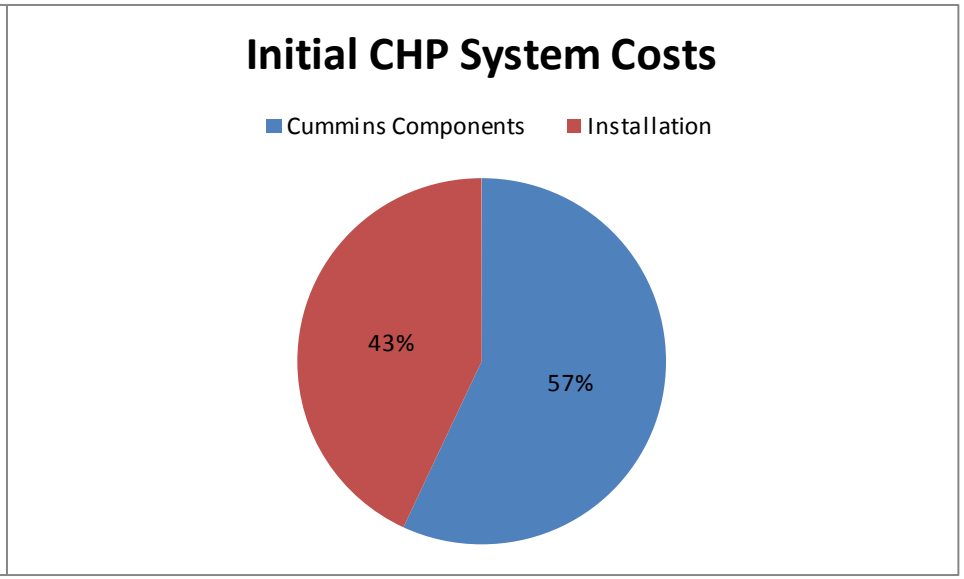
330 kW_e Integrated CHP System

- **Project Objective**: Increase small-scale CHP adoption in the United States
- **Current State of the Art**
  - Site specific engineering
  - Limited packaged CHP options
- **Remote Monitoring & Control**: Reduce operating & maintenance costs
- **System Efficiency**: Calculated 74% HHV
- **Emissions:** Cooled exhaust gas recirculation (EGR) with three-way catalyst (TWC) to achieve most aggressive U.S. emissions requirements
- **Deployment**: Intended markets include small industrial, commercial, & institutional customers with hot water & electrical needs
- **Benefits**
  - Reduce CO_2 emissions & energy consumption
  - Lower product cost from mass-market engineering development
- **Commercialization**: Use existing Cummins engineering methods, distribution channel, and support
- **Project Management**: 3 fiscal quarters into a three year, $8.2M project
- **Accomplishments**
  - Voice of the Customer: Interviews & translation into product requirements
  - Base Engine: Operational in test cell
- **Path Forward**
  - Deliverables currently on track
  - Gate 3 review end of FQ2 2013

Project Objective

- Increase the adoption rate for high-efficiency Combined Heat and Power systems via development of a flexible, containerized 330 kWe unit that simplifies installation, reduces total cost of ownership, and meets all United States emissions regulations.





State of the Art

Cummins Power Generation

- Site-specific engineering (Energy Solutions Business)
- Incident-based diagnostics
- Time-based maintenance
- Serviced on-site by distributors

Emissions	Currently available product	Project goals
NOx (lb/MW-hr)	3.1	0.07
CO (lb/MW-hr)	6.5	0.10
VOC (lb/MW-hr)	0.93	0.02

Engine Efficiency	Currently available product	Project goals
Brake Thermal Efficiency (%)	36	39

State of the Art

Competition

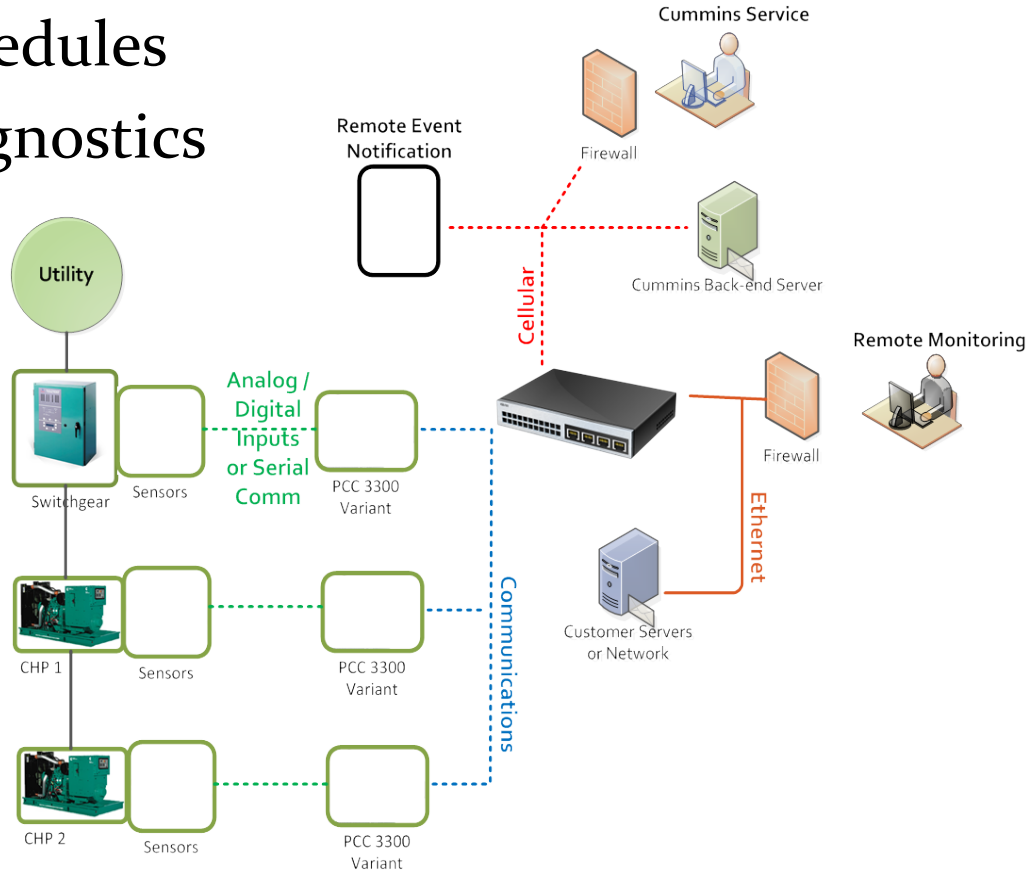
- Numerous attempts limiting adoption
  - Components reliability
  - Maintenance and service issues
  - System misapplication
  - Lack of performance information and tracking
- Result: regionally poor reputation, abandoned systems

Technical Approach

Controls Development

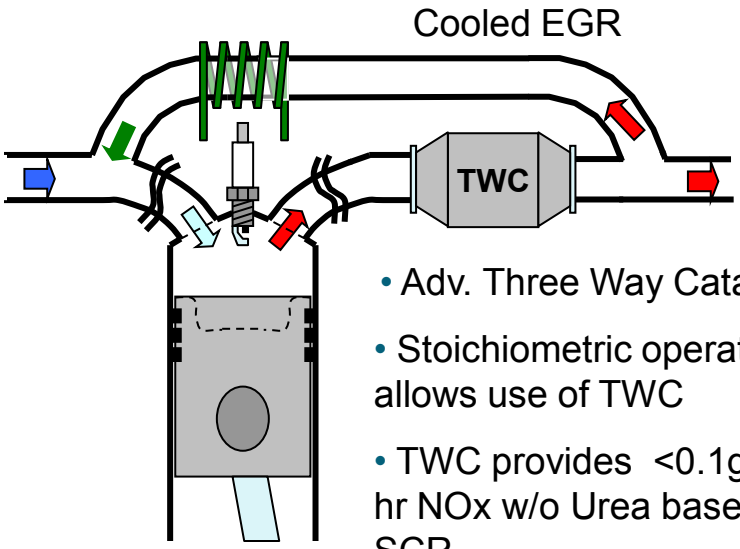
- Predictive Service and Advanced Diagnostics (PSAD) – *Reducing Maintenance Cost*
  - Predictive service for components and consumables
  - Custom maintenance schedules
  - Proactive component diagnostics

- Remote monitoring and control – *Reducing Total Cost of Ownership*
  - Off-site operators
  - Web/cellular access



Technical Approach

Engine Development

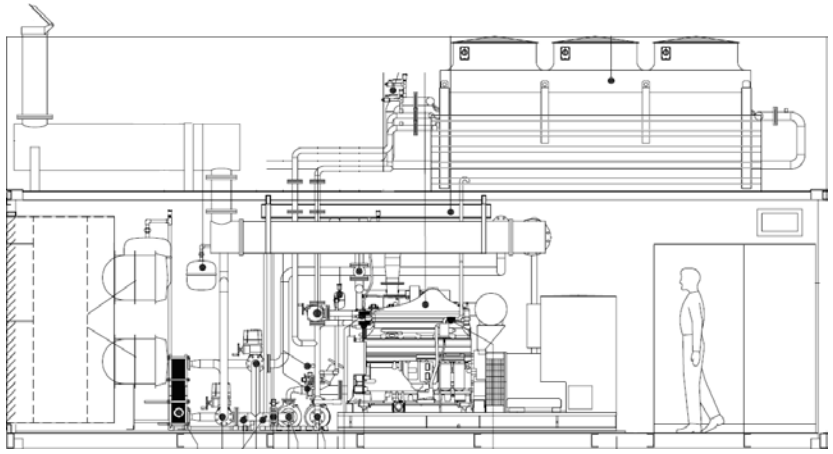


- QSK19 – Natural Gas Engine
- Technology and aftertreatment system will be developed and optimized to integrate into the CHP system
  - New air handling system (EGR, turbo, coolers)
  - Optimized aftertreatment and controls
- Cooled EGR with advanced three-way catalyst
  - Emissions target - stringent CARB NOx standard

Transition and Deployment

Target Markets

- Small Industrial
  - chemical production
  - food processing
  - heat molding / plastics
- Commercial
  - laundries
  - hospitals and nursing homes
  - hotels and resorts
- Institutional
  - schools and universities



Gas & Electric Utilities

Emissions Regulators

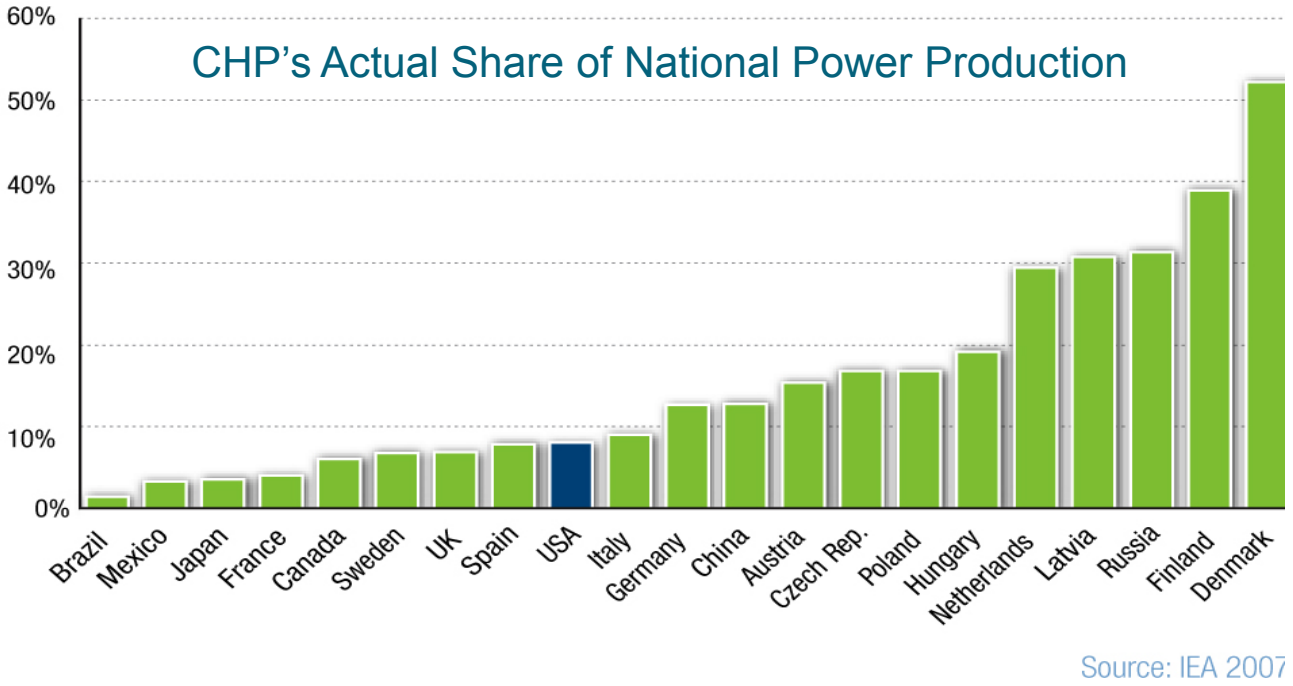
Transition and Deployment

Technology Sustainment

- 330kWe prototype will be the first product in a family of Cummins Power Generation packaged CHP systems below 1MW, covering 4-6 power nodes
  - Cummins Value Package Introduction process utilized for commercialization
  - 165,000 potential sites for 100-500kWe system – enhances prospects for full range of commercialization

Measure of Success

- Transition DOE prototype to mass production
  - Positive feedback from sales reps and customers
  - Further improve product via remote data collection
- Enhance customer perception of CHP systems
  - Increase United States CHP system adoption rates



Benefits

Energy Reduction Calculations

- Reduction in total fuel consumed per year per unit = 37%
- Assuming conservative cumulative sales by 2020, total savings equate to 15 TBtu/yr or 58 TBtu/yr for an expanded product range

Assumptions for Energy Benefits Calculation

Gen Set Efficiency	37%		**Water Heater Eff. (LHV)**	95%
Avg. Grid Eff. (LHV)	30%		**CHP System Uptime**	8,000 hrs/yr

Emissions Reduction Calculations

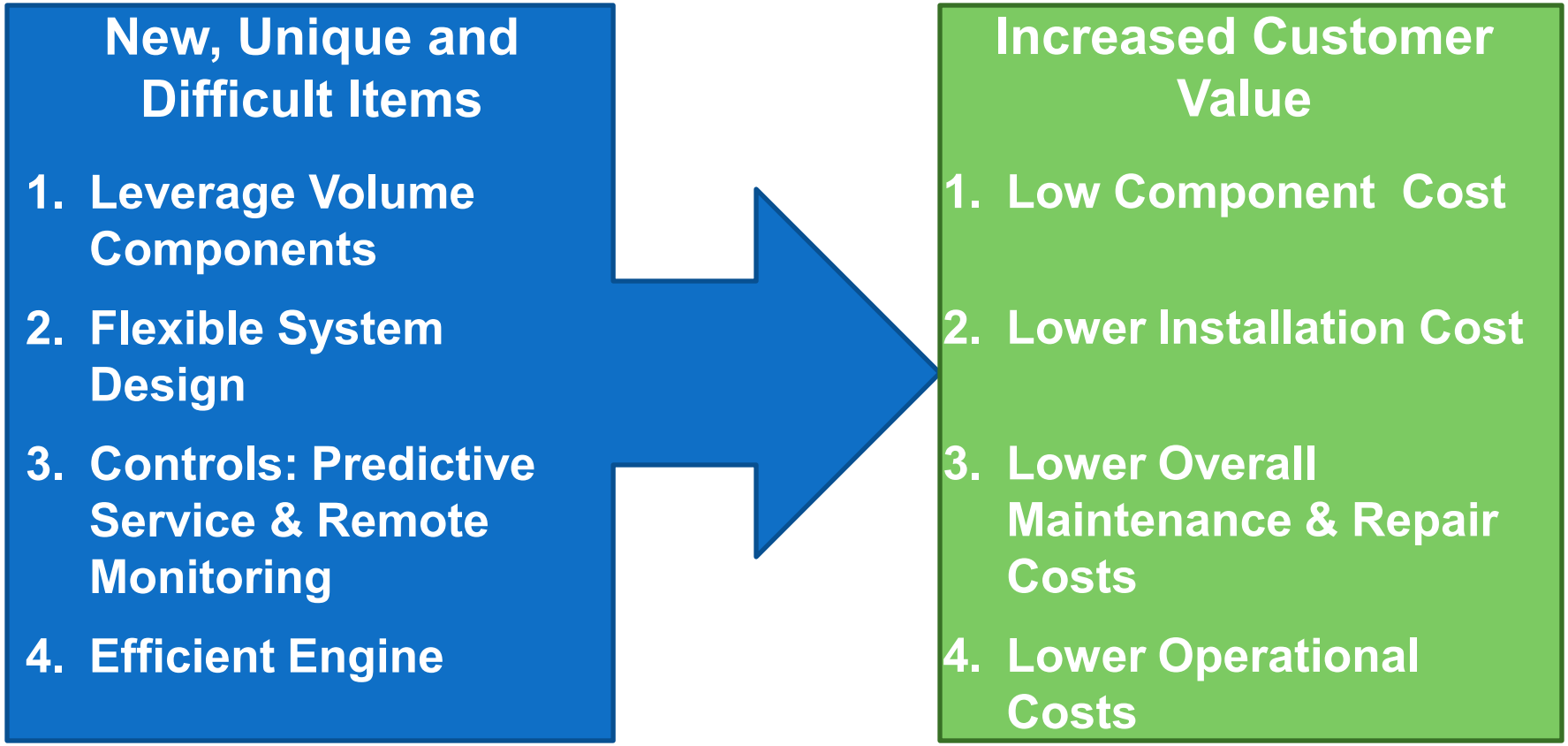
- Reduction in CO2 emissions by 1 mm tons/yr or 4 mm tons/yr for an expanded product range

Assumptions for Emissions Benefits Calculation

Standard Grid Elec.	169 kg-CO_2/GJ_e		**Nat. Gas CO_2**	50 kg-CO_2/GJ_e

Benefits

Benefits of engineering a modular 330 kWe CHP system



Commercialization Approach

Customer Value

- Maximize system flexibility to accommodate a wide variety of potential end-use candidates

Channel to Market

- Dedicated Distribution system of 14 distributors with 145 locations in the United States
- Comprehensive warranty and optional maintenance contracts
- Cummins to provide solutions to all system problems

Project Management & Budget

Budget Period 1

Oct 2010-Sept 2011

Concept Development

- Competitive analysis and VOC complete – product requirement summary
- Engine aftertreatment and controls meets specifications
- CHP / genset controls features implemented in software

Budget Period 2

Oct 2011-Sept 2012

Prototype Development

- Engine and Genset performance verified in test cell
- CHP model efficiency 70% HHV or greater

Budget Period 3

Oct 2012-Sept 2013

Commercial Testing

- Packaging design complete
- CHP system operational
- Aux cooling system validated in test
- Predictive service features implemented
- Full system integration and testing complete
- 3-month field demonstration

Project Management & Budget

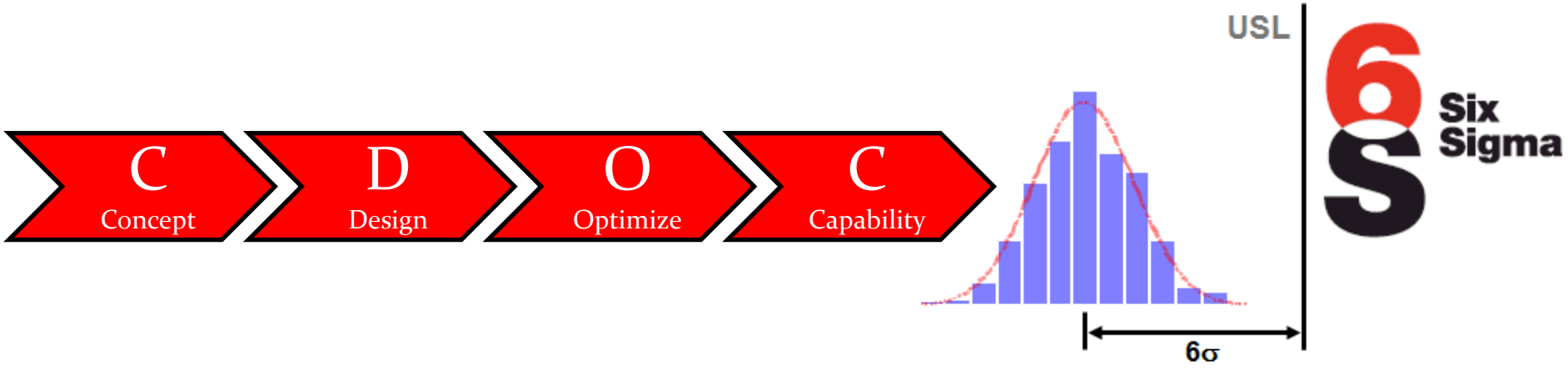
- Cummins / DOE Cost Share Over Three Year Program
  - 70 / 30 (DOE / Cummins) split through first half of FY 2013
    Gate 3 – (Concept and Prototype development)
  - 50 / 50 split during second half of FY 2013
    Gate 4 – (Commercial Testing)

Project Budget				
	FY11	**FY12**	**FY13**	**FY14**
DOE Investment	$ 2.61 M	$ 1.53 M	$1.09 M + $ 359 K	NA
Cost Share	$1.12 M	$ 657 K	$ 469 K + $ 359 K	NA
Project Total	**$ 3.73 M**	**$2.19 M**	**$2.28 M**	NA

Results and Accomplishments

Voice of the Customer (VOC)

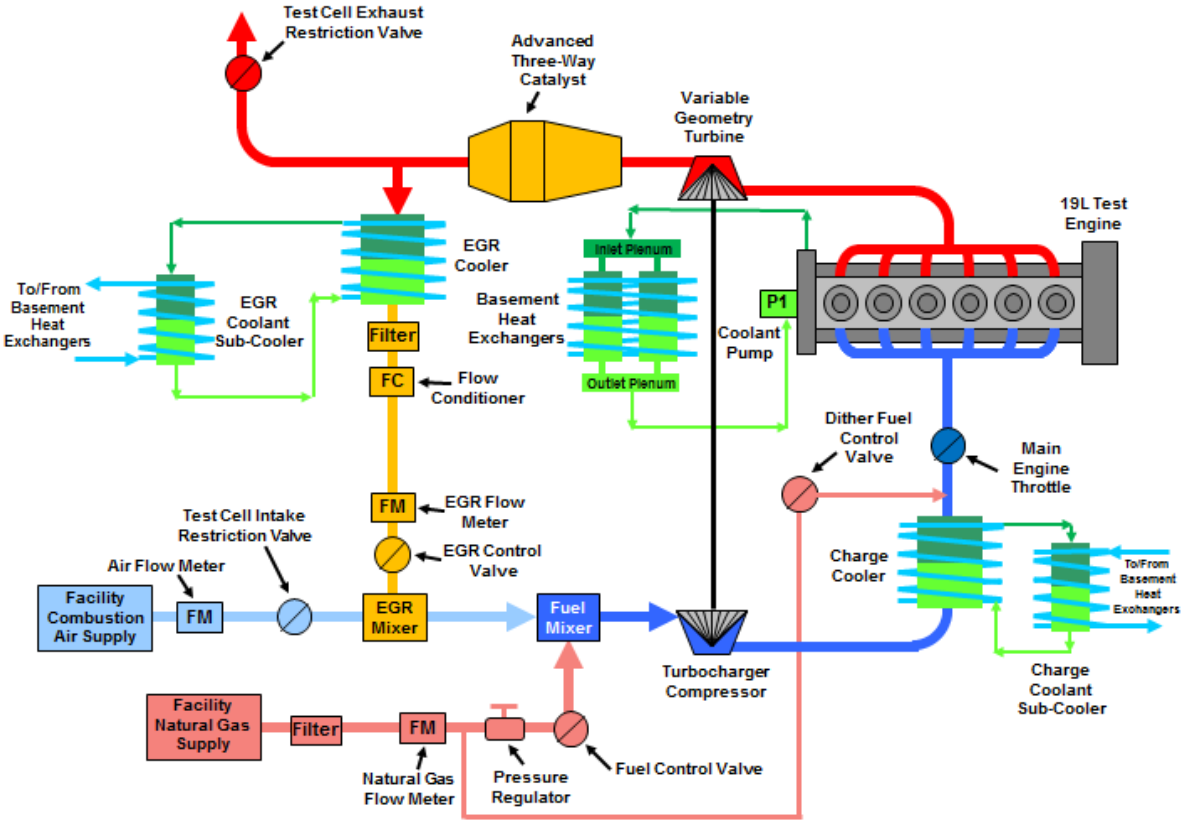
- Completed 35 internal and external interviews totaling over 1000 statements
  - Engineering, marketing, consulting, distribution, utilities, customers
- Derived Value Package Profile and Best Practice Competitive Analyses, resulting in 107 Technical Requirements, examples of which include:
  - CHP system shall provide a simple, standard electrical and mechanical interface with a high degree of serviceability.
  - CHP system shall provide information to the user regarding financial benefits.
  - CHP provider shall assume responsibility for everything in the system – customers expect to call one firm to fix all issues.
  - CHP system shall comply with all regulatory agency requirements.

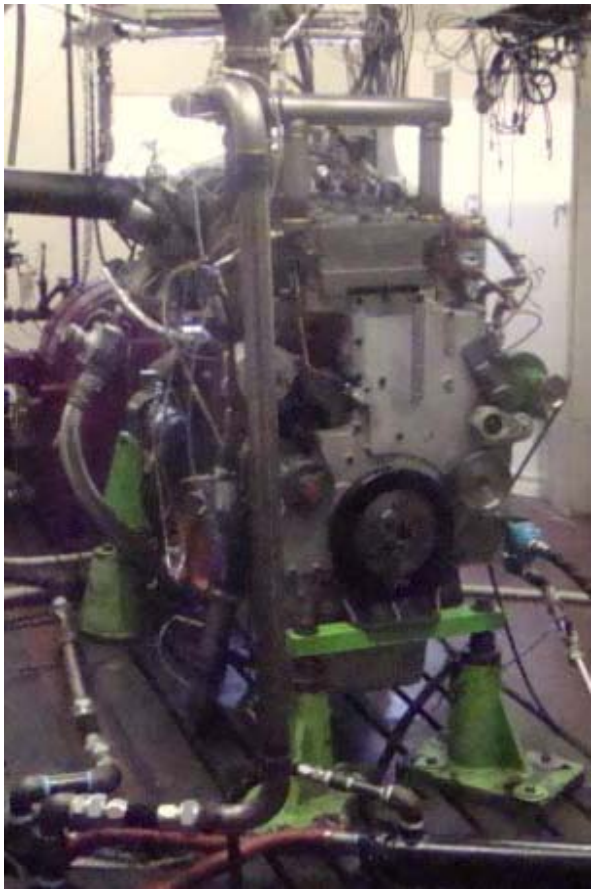


Results and Accomplishments

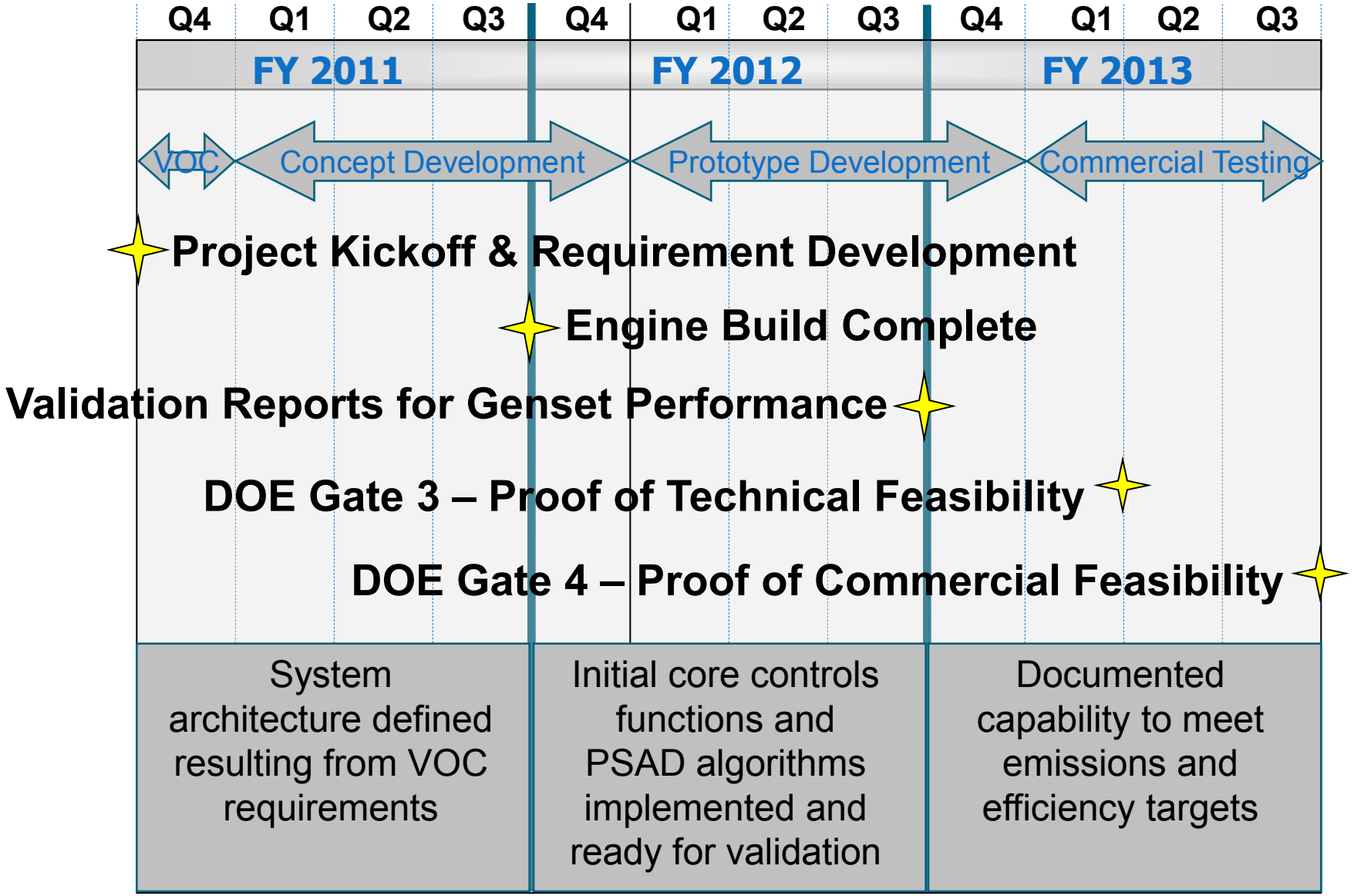
CHP Engine

- CHP Test Cell Layout





Path Forward



Path Forward

Project Quarter	Packaged CHP Project Deliverable
Q1	Potential customers identified, questionnaire developed for VOC
Q2	Product requirement summary resulting from the KJs
Q3	CHP control features implemented in software
Q4	Engine build complete
Q5	Summary of heat recovery system and expected performance from modeling
Q6	System performance and robustness summary document (Engine)
Q7	Stable Genset design documents
Q8	Validation reports for genset performance
Q9	Validation reports (auxiliary cooling system)
Q10	Total CHP packaging solution
Q11	System performance test summary
Q12	Emissions and efficiency report

Questions?