California Energy Commission
Staff Workshop
Building and Community Scale Renewable Technology Costs
August 25, 2009

2009 Cost of Generation Study

California Energy Commission
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Workshop Presentation

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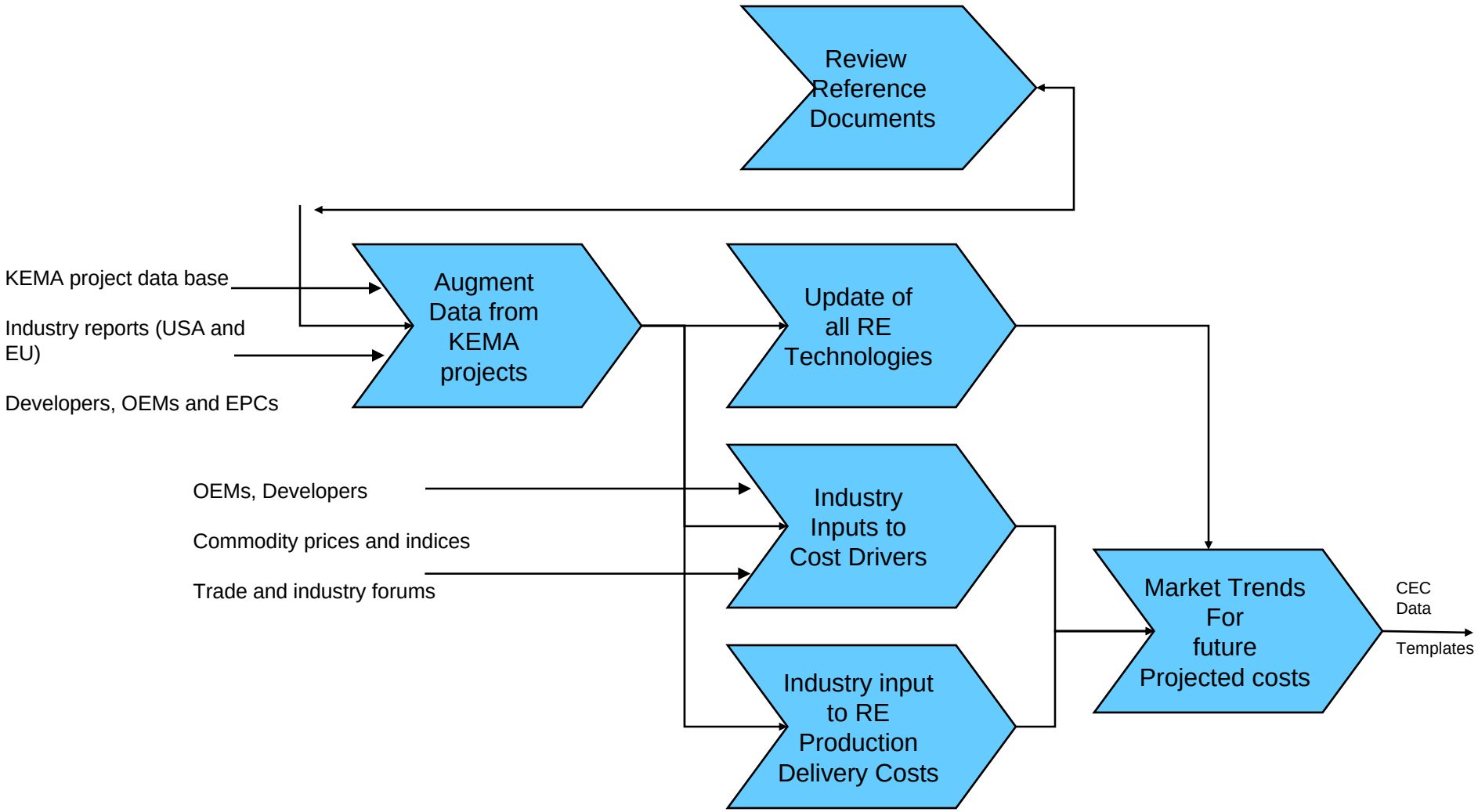
Approach and Methodology

The research team undertook the following approach:

- Conducted a technical and analytical critique of reference documents. Key reference documents included:
  - *Renewables for Heating and Cooling*, July 2007 report from the International Energy Agency.
  - CEC Contractor's Draft Report: Cheremisinoff, Nicholas, Kathryn George, and Joseph Cohen. 2009. *Economic Study of Bioenergy Production From Digesters at California Dairies.* California Energy Commission, PIER Program. CEC-500-2009-058.
- Recommended building and community scale RE technologies for cost analysis with technical and market justification. Building and community scale technologies are generally defined as those below 20 MW.
- Identified the primary existing commercial embodiment of each building and community-scale technology in California.
- Identified the expected primary commercial embodiment in the year 2018.

Approach & Methodology



Technology Selection Criteria

The research team used selection criteria similar to the following:

Example Sample criteria:

- Is the technology commercially available and is anyone using it?
- How many projects worldwide are initiated?
- Is the technology commercial somewhere, not necessarily in CA?
- What is the building and/or community-scale capacity that would apply to CA?
- Are there any things that make it difficult to make it viable in CA?
- What's going on in the world, what's commercial, what's being purchased?
- What's viable in CA and what could become viable, and what would it take to make it viable?
- Political climate and statewide policy

Renewable Energy Technologies – Building and Community Scale

Technology List	Average Capacity
Biomass – Dairy or Swine Manure	
Biomass – Advanced Digester (Food Industry – Biogas Application)	550 kW electric
Biomass – Landfill Gas (LFG)	Up to 2,000 kW electric
Biomass – Waste Water Treatment Plant (WWTP)	5,000 kW electric (5 MW)
Geothermal	
Geothermal – Heat Pumps	150 tons cooling
Hydropower	
Hydro – In Conduit	1100 kW electric
Solar	
Solar – Photovoltaic Residential Fixed Tilt	5.3 kW electric
Solar - Photovoltaic Commercial Fixed Tilt	138 kW electric
Solar – Photovoltaic Ground-Based Tracking	1500 kW electric
Solar – Integrated Space and Water Heating	4.4 kW thermal
Solar – Residential Water Heating	116 therms/year
Wind	
Wind – Community Scale	5,000 kW (5 MW)

Building and Community Scale Technologies – Unique Issues

Issue Specific to Building and Community Scale	Cost, Market, or Technology Impacts
Technologies not as discrete as Utility Scale	Many variations in application and approach, which can fragment market and cloud cost projections.
Often need incentives to promote adoption	Incentives are significant market drivers as long as the market believes they will be consistent over a period of time. Absent consistency, there is risk, which may lead to suppliers exiting or not entering market.
Installation contractor size, scope and expertise	Smaller-scale renewable technology adoptions are performed by a wide array of installation contractors and suppliers, much more so than at utility scale.
Potential for technology advancement	Some technologies are very mature; other technologies could be improved from both a technical and cost standpoint.
Cross-platform technologies require integration	Many technologies are cross-platform, and can involve multiple lines of business. For example, integrated solar requires solar design, HVAC equipment, and roofing/structural expertise. Geothermal requires well-drilling, piping/plumbing, engineering and HVAC expertise. Today, small integrators pull them all together, but there is not one discrete offering.

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Solar Water Heating - Residential

Biomass – Technologies Overview

Digester, Landfill Gas and Wastewater Treatment applications are mature renewable technology applications in California.

Biomass Technologies Selected:

- ❑Advanced Digester – Food Industry (Biogas)
- ❑Landfill Gas Power Generation
- ❑Waste Water Treatment Plant Application

Photo credit: Journal of Commerce (Canada), interfaceglobal.com

Biomass – Digester Technologies
Types of Technologies

Advanced anaerobic digester technologies benefit the food industry through reducing organic wastes and producing high-quality methane for power uses.

Digester Technologies remain the same for application such as food	**Biomass – Types of Technologies (anaerobic)** **Covered Lagoon:** Simplest to manage and operate. Essentially a deep pit with cover over top. The volume of the lagoon matches the retention time for waste in the lagoon – generally 40 to 60 days. Preferred only in warm climates. Requires liquids with less than 3 percent solids. **Complete Mix:** Engineered tanks that treat slurry with a solids concentration in range of 3-10%. Requires less land than lagoons and tanks are typically heated, allowing operation in all climates. **Plug Flow Digesters:** Engineered, rectangular tanks that treat scrapped effluent with a range of 11-13 % solids. Swine manure can not be used due to lack of fiber. **Fixed Film Digesters:** Tanks filled with plastic media that supports a thin layer of anaerobic bacteria called biofilm. Requires dilute waste streams typically 3% or less.
	Reference Material: see "Task 1- Central Plant Technologies.xls" EPA AgStar Handbook

Biomass – Digester Technologies
Summary of Digester Characteristics

Advanced technologies reduce retention times (allows greater volumes to be passed through system – more biogas)

With Food Waste or Waste Water, large flows move developers to technologies with lower retention times

Biomass – Types of Technologies (anaerobic)

Characteristics	Covered Lagoon	Complete Mix Digester	Plug Flow Digester	Fixed Film
Digestion Vessel	Deep Lagoon	Round/Square In/Above-Ground Tank	Rectangular In-Ground Tank	Above Ground Tank
Level of Technology	Low	Medium	Low	Medium
Supplemental Heat	No	Yes	Yes	No
Total Solids	0.5 - 3%	3 - 10%	11 - 13%	3%
Solids Characteristics	Fine	Coarse	Coarse	Very Fine
HRT* (days)	40 - 60	15+	15+	2-3
Farm Type	Dairy, Hog	Dairy, Hog	Dairy Only	Dairy, Hog
Optimum Location	Temperate and Warm Climates	All Climates	All Climates	Temperate and Warm

* Hydraulic Retention Time (HRT) is the average number of days a volume of manure remains in the digester.

Reference Material: see "Task 1- Central Plant Technologies.xls"

EPA AgStar Handbook

Biomass – Digester Technologies
How to make digesters advanced

Techniques have been used with complete mix.

Example of fixed film, single stage Digesters

Biomass – Types of Technologies (anaerobic)

Thermophilic: Microbes that thrive in temperatures of 120-140 degrees F. Most often used at Waste water treatment facilities where there is process or heat loads to heat the digester and to consume energy. CHP systems are great uses for the digester gas to offset the heat required for the digester to maintain operations. Also best for 24-7 operation as system requires high level of maintenance – if temperature drops, can loose microbe population.

Most digesters are mesophilic that operate in a range of 85-95 degrees F.

Single vs. Two Stage: The biogas process involves two steps of acid production and methane production. These processes optimize at different acidic levels. Separating the processes allows each stage to be optimizes and results in higher, more "pipeline" like quality of gas.

This results in less clean-up equipment required and greater solids destruction from the digester process.

Reference Material: see "Task 1- Central Plant Technologies.xls"

"The Microbiology of Anaerobic Digesters", Michael Geardi

Biomass – Advanced Digester Food Industry (Biogas) Key Cost Influences

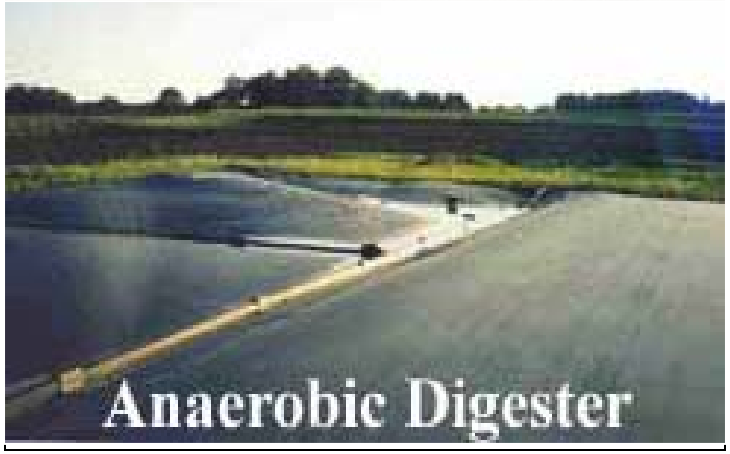
Advanced anaerobic digester technologies benefit the food industry through reducing organic wastes and producing high-quality methane for power uses.

Key Cost Influences	**Biomass – Advanced Digesters (anaerobic) for Food** **Type of Food:** Each type of food waste varies in volatile solids and % solids in waste. Compared to Dairy Manure, waste streams have many more times the level of Volatile Solids that will result in higher quantities of biogas **Capacity Factor:** Increased gas allows for high levels of capacity factors. However, gasification technology only produces gas for a fuel and capacity factor depends on technology which is typically a reciprocating engine. Food waste produces a higher quality gas which results in less maintenance downtime and results in CFs that equal typical IC engines. Capacity factors typically range of 80-90%. **Installed Costs:** Depends on the size of generator selected for electricity and type of digester selected for gas production. Costs range from $4,000 to $6,000 per kW. **Single Facility Applications:** As food processors tend to be set in industrial areas, ability to form community applications are limited. kW size will range from 75 kW to 5 MW.
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Biomass – Advanced Digester Food Industry (Biogas) Selected Technology Description

Advanced anaerobic digesters have multiple applications in the California food industry. Advantages of California project are displayed below

Typical Plant



Description

Valley Fig Growers in California constructed covered lagoon system to use waste from cleaning and rehydration of dried figs

Benefits include

- BoD and suspended solid reduction of 80%
- Utilizes a 70kW generator
- Waste heat captured to increase digester efficiency of plant
- Provides 90% reduction in waste water
- Strength reduction equates to $112,000 savings in annual sewer bill savings

Biomass – Advanced Digester Food Industry (Biogas) Cost Drivers

AD Biomass Technologies build on previous mature technologies to provide better waste decomposition and biogas production.

Cost Drivers

Key Cost Drivers

- Type of food that can be utilized for waste - key determinate in amount of biogas created (off-spec milk from dairy farms has 100,000 times the levels of manure)
- Amount of gas cleanup equipment
- Initial capital cost
- Ability to utilize waste heat, either at the plant or to increase digester efficiency

Plant Configuration Data Overview (Plug Flow)

2.0.3 - Installed Costs:	Units	Min	Average	Max
Installed Cost Range:	$/kW	$2,033	$4,769	$15,250
Average Installed Cost:	$/kW		$4,769	

3.0 - Cost Driver and Experience Curve:	Units	Start Year Values		
		2009	2015	2020
Technology Progress Ratio:	%/yr	0.0%	1.0%	1.0%

4.0 - Operating Costs and Data:	Units	Min	Average	Max
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 155.81	$ 178.43	$ 219.54
Capacity Factor:	%/yr	77.0%	82.4%	91.4%
Annual Operating Hours (calculated):	hr/yr	6,745	7,218	8,007
Outage Rate (%/yr)			17.6%	
Performance Degradation (%/yr)			0.0%	
Transmission Losses (%)			0.0%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-

5.0 - Financial and Investment Data:	Units	Min	Average	Max
System Life (years)		20	20	20
Interest Rate:	%/yr		7.0%	
Annuity Factor: (calculated):	-		9.4%	
Annual Investment Cost (calculated):	$/kW-yr		$477.16	

Biomass – Advanced Digester Food Industry (Biogas) Current Cost and Cost Trajectory

Is market expected to see significant price reductions?

Current Costs (Plug Flow)

		2009	2010	2011
IEPR Price Deflator:		1	1.0149	1.0312
Experience Curve Ratio - Installed Cost:		1.000	1.000	1.000

Investment Cost Trajectory ($/kW)		2009	2010	2011
Installation - Average	$/kW	$4,769	$4,840	$4,918
Installation - High	$/kW	$15,250	$15,477	$15,726
Installation - Low	$/kW	$2,033	$2,063	$2,096

Annual Investment Costs ($/kW-yr):		2009	2010	2011
Average	$/kW-yr	$477.16	$484.26	$492.04

Fuel, Energy and O&M Costs ($/kW-yr)		2009	2010	2011
Fuel Cost - Average	$/kW-yr	$ -	$ -	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -	$ -	$ -
Annual O&M Cost - Average	$/kW-yr	$ 178.43	$ 181.09	$ 184.00

Total Annual Energy Costs:		2009	2010	2011
Average	$/kW-yr	655.59	665.35	676.05

Total Annual Energy Output:		2009	2010	2011
Average	kWh/yr	3,271,306	3,271,306	3,271,306

Total Output Through System Life:		Total
Average	kWh	68,697,434

Projections

Price Trajectory

Costs are not expected to change dramatically. Very mature market on the generation side as well as the digester side.

Difficult for advanced digesters to provide a greater production that results in advancing technologies further than at current state. Mainly one-off projects prevent new applications from being replicated on a large scale

Facilities with little ability to provide maintenance should focus on simple, mature technologies. For facilities that have a greater ability to maintain systems (24/7 facilities) may want to use more advanced applications in order to increase gas production and thus electricity production.

Biomass – Landfill Gas (LFG)
Key Cost Influences

Landfill gas collection and generation technology is a mature, time-tested method for capturing methane and generating power from decomposing waste biomass.

Key Cost Influences	**Biomass – Landfill Gas Collection and Power Generation** **Capacity Factor:** Main component is a generator technology. Majority of technologies are reciprocating engines. Impact of low Btu gas from LFG is reduced efficiency (about 10%) and reduced power output (about 10%). Non-factor as fuel is essentially free. **Installed Costs:** Installed costs are typically 5% higher due to equipment modifications (fuel injectors, larger manifolds, less efficiency). Average is about $2,000/kW. **Fixed O&M:** Dealing with impurities and cleaning the gas results in O&M that is roughly 20% higher than normal operation. This extra cost tends to be for fuel treatment, H2S filters, and siloxane filters. Siloxanes are becoming increasingly problematic. They typically are sourced from human cleaning products (soaps, shampoos), flow through the gas, and the results are residues that remain in generator after combustion. They are particularly problematic for combustion turbines as the residues tend to line turbine blades. ICs, though less susceptible, still need to manage the issue.
	Reference Material: see "Task 1- Central Plant Technologies.xls" EPA Landfill Methane Outreach program. Resource Dynamics Corporation, DOE study

Biomass – Landfill Gas (LFG)
Selected Technology Description

Landfill Gas technologies are mature, and most technical issues are known. LFG gas production can sometimes vary with time and waste contents.

Typical Plant	Description
 Landfill Gas Application	California has roughly 100 Landfill gas fields under production. MW of the systems range from 100kW to 50 MW. Average system is 3.8MW and are typically reciprocating engines The state has another 34 additional candidate landfills (approximately 136 MW) and 194 additional potential sites. Many potential sites have “low kW capabilities” often around 100 kW

Biomass – Landfill Gas (LFG)
Cost Drivers

Landfill Gas technologies are mature, and most technical issues are known. Cost drivers are simply from additional equipment and maintenance due to gas.

Cost Drivers

Key Cost Drivers

- Required modifications to engine for gas cleanup
- Engine susceptibility to siloxanes
- Impact of low-medium Btu gas on engine itself
- Due to location, few opportunities to increase payback with CHP systems as typically there is no need for waste heat

Plant Configuration Data Overview

Technology Cost Input Data:

1.0 - Capacity:	Units	Min	Average	Max
Capacity Range:	kWe	100	3,800	50,000
Average Capacity:	kWe dc		3,800	

2.0 - Installed Costs:	Units	Min	Average	Max
Installed Cost Range:	$/kW	$1,000	$2,000	$2,400
Average Installed Cost:	$/kW		$2,000	

3.0 - Cost Driver and Experience Curve:	Units	Start Year Values		
		2009	2015	2020
Technology Progress Ratio:	%/yr	1.0%	1.0%	1.0%

4.0 - Operating Costs and Data:	Units	Min	Average	Max
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 73.91	$ 189.87	$ 319.30
Capacity Factor:	%/yr	75.0%	85.0%	90.0%
Annual Operating Hours (calculated):	hr/yr	6,570	7,446	7,884
Outage Rate (%/yr)			15.0%	
Performance Degradation (%/yr)			0.0%	
Transmission Losses (%)			1.0%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-

5.0 - Financial and Investment Data:	Units	Min	Average	Max
System Life (years)		10	10	10
Interest Rate:	%/yr		7.0%	
Annuity Factor: (calculated):	-		14.2%	
Annual Investment Cost (calculated):	$/kW-yr		$284.76	

Biomass – Landfill Gas (LFG)
Cost Drivers

Landfill gas technology is mature and well known. Few surprises or technology innovations are expected.

Current Costs

Technology Investment and Energy Costs:

6.0 - Total Investment and Energy Costs: (Output)

		2009	2010
IEPR Price Deflator:		1	1.0149
Experience Curve Ratio - Installed Cost:		1.000	0.990

Investment Cost Trajectory ($/kW)		2009	2010
Installation - Average	$/kW	$2,000	$2,009
Installation - High	$/kW	$2,400	$2,411
Installation - Low	$/kW	$1,000	$1,005

Annual Investment Costs ($/kW-yr):		2009	2010
Average	$/kW-yr	$284.76	$286.10

Fuel, Energy and O&M Costs ($/kW-yr)		2009	2010
Fuel Cost - Average	$/kW-yr	$ -	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -	$ -
Annual O&M Cost - Average	$/kW-yr	$ 189.87	$ 192.70

Total Annual Energy Costs:		2009	2010
Average	$/kW-yr	**474.63**	**478.80**

Total Annual Energy Output:		2009	2010
Average	kWh/yr	23,810,074	23,810,074

Total Output Through System Life:		Total
Average	kWh	500,011,558

Projections

Price Trajectory

Costs are not expected to change dramatically. Very mature market on the generation side as well as the digester side.

Difficult for advanced digesters to provide a greater production that results in advancing technologies further than at current state.

Facilities with little ability to provide maintenance should focus on simple, mature technologies. For facilities that have a greater ability to maintain systems (24/7 facilities) may want to use more advanced applications in order to increase gas production and thus electricity production.

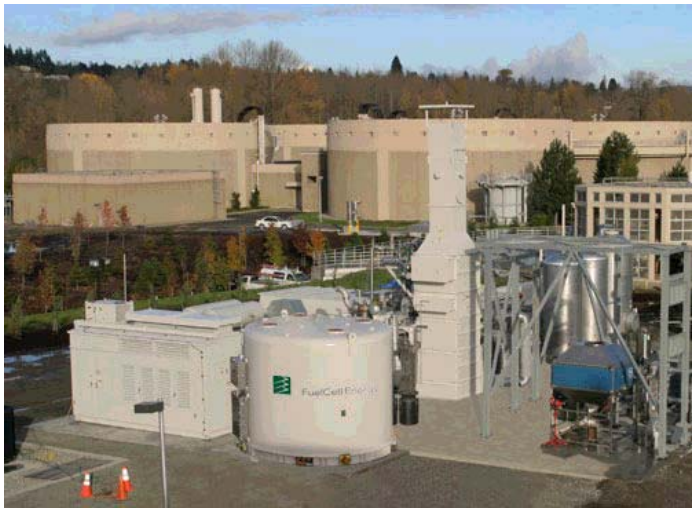
Biomass – Waste Water Treatment Plant (Biogas)
Key Cost Influences

Advanced digester technologies such as thermophilic devices can be used to increase the applicability of this community-scale technology

Key Cost Influences	**Biomass – Advanced Digesters (anaerobic) for Food WWTPs:** All Digester technologies can be utilized at Wastewater Treatment Facilities. However, potential to run large systems – 5 to 10 MW, 24/7 operations, and skilled maintenance personnel provide opportunity for innovative and advanced systems to be utilized, such as advanced, two-stage, thermophilic digesters **Capacity Factor:** Capacity factor depends on technology which is typically a reciprocating engine. Range of 80-90% is expected to be high due to advanced digester producing higher quality methane gas. **Installed Costs:** Depends on the size of generator selected for electricity and type of digester selected for gas production. Costs range from $3,000 to $6,000 per kW. Note that Digesters are not standardized applications. However, these applications will typically be cogeneration systems. **Single Facility Applications:** As Waste Water Treatment Plants tend to be set in industrial areas, ability to form community applications are limited. kW size will range from 1 MW to 5 MW.
	Reference Material: see "Task 1- Central Plant Technologies.xls" DOE EERE Federal Energy Management Program data, KEMA KEMA data on WWTP digester projects

Biomass – Waste Water Treatment Plant (Biogas) Selected Technology Description

Both microturbines, fuel cells, and reciprocating engines have been used to generate reliable power from biomass decomposition in wastewater treatment plants.

Typical Plant	Description
 1 MW Fuel Cell Plant at King County Waste Water Treatment Facility	Originally was a focus on advanced energy technologies such as microturbines and fuel cells. However, reciprocating engines or gas turbines tend to be the preferred, cheaper alternative currently.

Biomass – Waste Water Treatment Plant (Biogas) Cost Drivers

Varying waste streams and decomposition products can impact biogas production and generation of power.

Cost Drivers

Key Cost Drivers

- Labor: Digester Type – WWTP digesters can use advanced digester applications such as two-stage, thermophilic systems. This may require skilled labor to attend and maintain systems
- Maintenance: Advanced digesters require maintaining temperature. Often, cogeneration systems are used in order to use the heat for digesters
- Higher quality gas: Costs are also lowered due to the higher quality gas produced by advanced digesters – decreasing need for gas clean-up
- Higher quality gas results in ability to use large generators, decreasing the $/kW initial cost

Plant Configuration Data Overview

Technology Cost Input Data:

1.0 - Capacity:	Units	Min	Average	Max
Capacity Range:	kWe	200	3000	5000
Average Capacity:	kWe dc		3000	

2.0 - Installed Costs:	Units	Min	Average	Max
Installed Cost Range:	$/kW	$3,044	$3,471	$4,074
Average Installed Cost:	$/kW		$3,471	

3.0 - Cost Driver and Experience Curve:	Units	Start Year Values		
		2009	2015	2020
Technology Progress Ratio:	%/yr	2.0%	2.0%	2.0%

4.0 - Operating Costs and Data:	Units	Min	Average	Max
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 100.92	$ 126.58	$ 189.41
Capacity Factor:	%/yr	80.0%	85.0%	93.0%
Annual Operating Hours (calculated):	hr/yr	7,008	7,446	8,147
Outage Rate (%/yr)			15.0%	
Performance Degradation (%/yr)			0.5%	
Transmission Losses (%)			0.5%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-

5.0 - Financial and Investment Data:	Units	Min	Average	Max
System Life (years)		15	15	15
Interest Rate:	%/yr		7.0%	
Annuity Factor: (calculated):	-		11.0%	
Annual Investment Cost (calculated):	$/kW-yr		$381.10	

Biomass – Landfill Gas (LFG)
Cost Drivers

WWTP gas technology is mature and well known. Few surprises or technology innovations are expected. However, advanced technologies can cause need for skill labor

Current Costs

Technology Investment and Energy Costs:

6.0 - Total Investment and Energy Costs: (Output)

		2009	2010
IEPR Price Deflator:		1	1.015
Experience Curve Ratio - Installed Cost:		1	0.980

Investment Cost Trajectory ($/kW)		2009	2010
Installation - Average	$/kW	$3,471	$3,452
Installation - High	$/kW	$4,074	$4,052
Installation - Low	$/kW	$3,044	$3,028

Annual Investment Costs ($/kW-yr):		2009	2010
Average	$/kW-yr	$381.10	$379.03

Fuel, Energy and O&M Costs ($/kW-yr)		2009	2010
Fuel Cost - Average	$/kW-yr	$ -	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -	$ -
Annual O&M Cost - Average	$/kW-yr	$ 126.58	$ 128.47

Total Annual Energy Costs:		2009	2010
Average	$/kW-yr	**507.68**	**507.50**

Total Annual Energy Output:		2009	2010
Average	kWh/yr	18,797,902	18,703,912

Total Output Through System Life:		Total
Average	kWh	375,629,342

Projections

Price Trajectory

Costs are not expected to change dramatically. Very mature market on the generation side as well as the digester side.

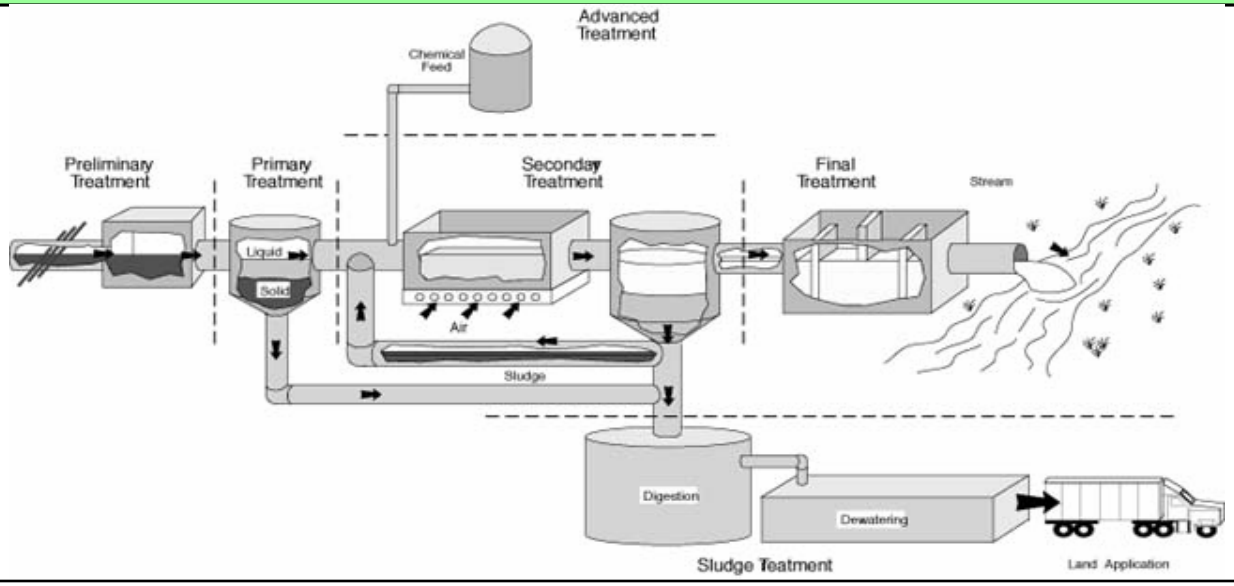
Most digesters require a high degree of customization. However, digesters at WWTP, because of the skill sets of personnel, running 24/7, and large amount of effluent flow, have the potential of utilizing advanced, two-stage, thermophilic digesters that can support larger systems.

Biomass – Waste Water Treatment Plant (Biogas) Current Cost and Cost Trajectory

Advanced, two-stage digester systems can be integrated into WWTPs and improve power generation potential.

Waste Water Treatment Process
All WWTP plants have a type of digesters. Solid contents of sludge (3% of less) provides the opportunity to use advanced digester technologies with sludge from primary and secondary treatment stages.

Typical WWTP Process

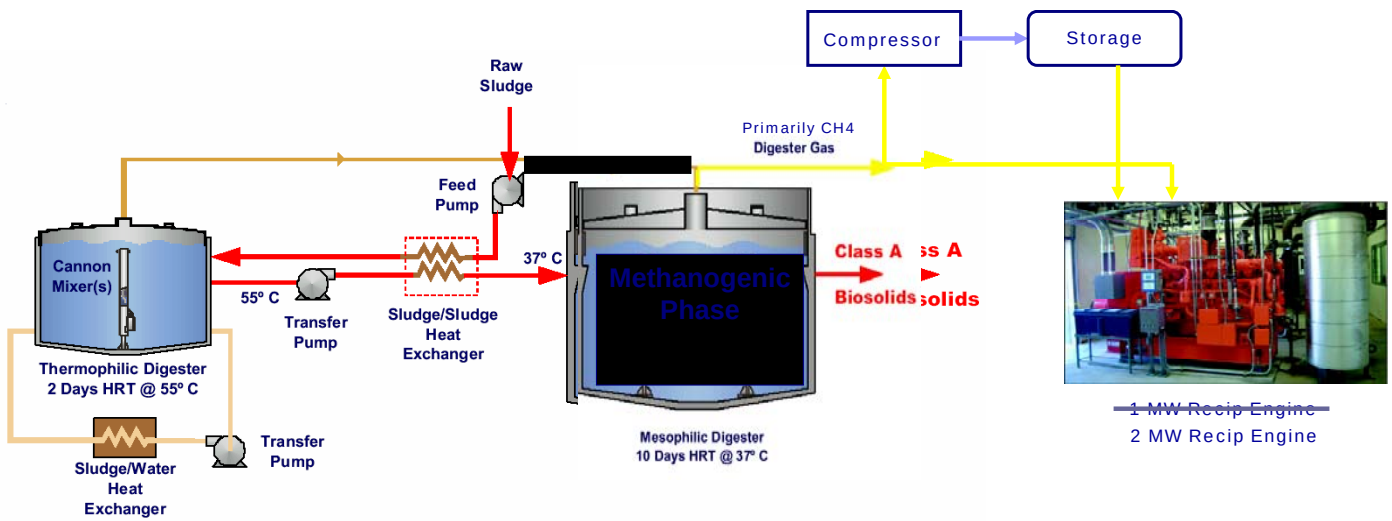


Biomass – Waste Water Treatment Plant (Biogas) Current Cost and Cost Trajectory

Advanced, two-stage digester systems can be integrated into WWTPs and improve power generation potential.

Current Costs
Advanced systems tend to be customized, but typically result in higher quality digester gas, larger generators, and a lower $/kW number.

Example of Advanced System



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Solar PV – Ground Based Tracking

Wind – Community Scale

Hydroelectric – In Conduit

Integrated Solar Space and Water Heating

Geothermal Heat Pumps

Solar Water Heating - Residential

Solar PV – Residential Fixed Tilt
Key Cost Influences

Residential PV costs are similar than commercial scale, though slightly higher.

Key Cost Influences	**Solar Photovoltaic – Residential Fixed Tilt** **Capacity Factor:** Varies dramatically on the location, amount of solar irradiance during a particular year, tilt angle, amount of shading, dirt and dust accumulation. From the California SGIP in 2006, the annual weighted average capacity factor was determined to be 16.2%. This results in a range of 14.1%-17.5%. **Installed Cost*:** Residential fixed-tilt systems range widely, from $3,000/kW - $21,000/kW, averaging $8,180/kW. **Fixed O&M:** Fixed O&M costs for flat plate PV range from $25-35/kW-yr, with an average of $30/kW-yr. In California, all major system components require a 10 year warranty per the CSI so O&M costs are foreseen to be minimal, but it is estimated the inverter will be replaced once during the life of the system. * Installed cost data taken from CSI database (all residential projects completed from Jan 2007 through April 2009).
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Solar PV – Residential Fixed Tilt
Selected Technology Description

Under the California Solar Initiative, most installed systems have been in the residential sector with a total capacity of 79 MW.

Typical Plant	Description
 Residential Roof-Mounted PV System Source: California Energy Commission	• **Residential Photovoltaic (PV) systems** include the PV modules themselves and the Balance of Systems (BOS). The BOS includes mounting structures, wiring, overcurrent protection and inverters (the electronic device that converts DC to AC electricity). • **Roof mounting**: One of the most common options for distributed generation (DG) PV is mounting the modules on the roof of a building. • **Types**: Modules can either be installed with specially designed mounting structures or integral to the roof membrane.

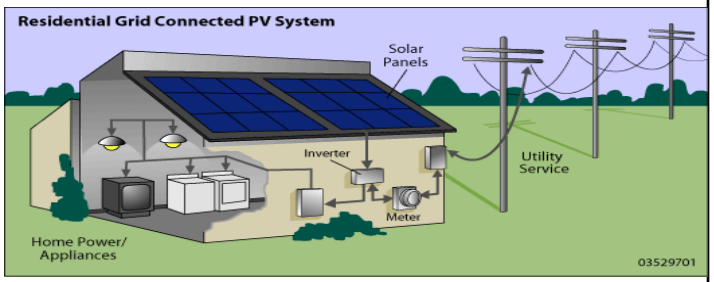
Solar PV – Residential Fixed Tilt
Cost Drivers

Continued technology advances in solar module design will result in significant lowering of residential installed costs over time.

Cost Drivers

Key Cost Drivers

- California Solar Initiative Incentives
- Installed Cost (module + BOS) - $3,000-$20,000/kW (average $8,180/kW)
- Fixed O&M - $25-35/kW-yr (average $30/kW-yr)
- Technology Advances
- Cumulative Installed Capacity



Plant Configuration Data Overview

Technology Cost Input Data:

1.0 - Capacity:	Units	Min	Average	Max
Capacity Range:	kWe	1.2	5.3	60
Average Capacity:	kWe dc		5.3	

2.0 - Installed Costs:	Units	Min	Average	Max
Installed Cost Range:	$/kW	$3,000	$8,180	$20,000
Average Installed Cost:	$/kW		$8,180	

3.0 - Cost Driver and Experience Curve:	Units	Start Year Values		
		2009	2015	2020
Technology Progress Ratio:	%/yr	2.2%	2.2%	2.2%

4.0 - Operating Costs and Data:	Units	Min	Average	Max
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 25.00	$ 30.00	$ 35.00
Capacity Factor:	%/yr	14.1%	16.2%	17.5%
Annual Operating Hours (calculated):	hr/yr	1,235	1,419	1,533
Outage Rate (%/yr)			2.0%	
Performance Degradation (%/yr)			1.0%	
Transmission Losses (%)			0.0%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-

5.0 - Financial and Investment Data:	Units	Min	Average	Max
System Life (years)		20	25	30
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.0%	
Annual Investment Cost (calculated):	$/kW-yr		$901.17	

Solar PV – Residential Fixed Tilt
Current Cost and Cost Trajectory

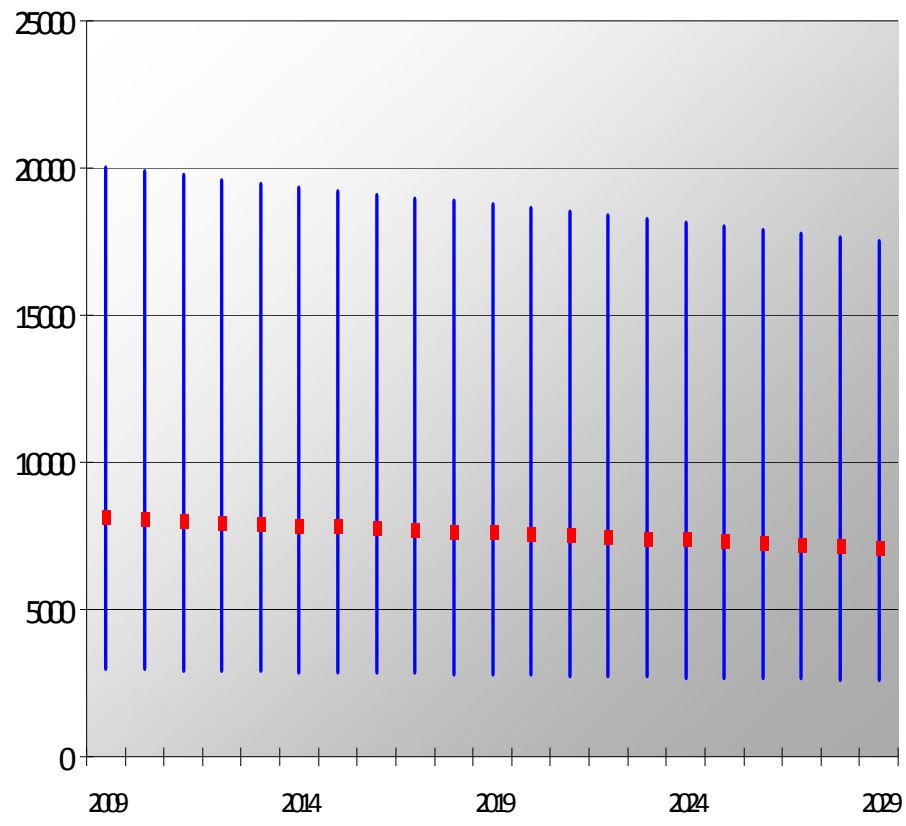
Technology advances in PV modules will reduce costs over time.

Current Costs

6.0 - Total Investment and Energy Costs: (Output)

		2009
IEPR Price Deflator:		1
Experience Curve Ratio - Installed Cost:		1
Investment Cost Trajectory ($/kW)		**2009**
Installation - Average	$/kW	$8,180
Installation - High	$/kW	$20,000
Installation - Low	$/kW	$3,000
Annual Investment Costs ($/kW-yr):		**2009**
Average	$/kW-yr	$901.17
Fuel, Energy and O&M Costs ($/kW-yr)		**2009**
Fuel Cost - Average	$/kW-yr	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -
Annual O&M Cost - Average	$/kW-yr	$ 30.00
Total Annual Energy Costs:		**2009**
Average	$/kW-yr	**$931.17**
Total Annual Energy Output:		**2009**
Average	kWh/yr	7,297

Installed Cost Projections ($/kW)



Solar PV – Commercial Fixed Tilt
Key Cost Influences

Overall the installed costs for fixed tilt systems is expected to decrease 2.2% per year through 2030 due to technology advances and learning effects.

Key Cost Influences	**Solar Photovoltaic – Commercial Fixed Tilt** **Capacity Factor:** Varies dramatically on the location, amount of solar irradiance during a particular year, tilt angle, amount of shading, dirt and dust accumulation. From the California SGIP in 2006, the annual weighted average capacity factor was determined to be 16.2%. This results in a range of 14.1%-17.5%. **Installed Cost***: Commercial fixed-tilt systems range widely, from $3,000/kW - $16,000/kW, averaging $7,680/kW. **Fixed O&M:** Fixed O&M costs for flat plate PV range from $25-35/kW-yr, with an average of $30/kW-yr. In California, all major system components require a 10 year warranty per the CSI so O&M costs are foreseen to be minimal, but it is estimated the inverter will be replaced once during the life of the system. * Installed cost data taken from CSI database (all commercial, government, and non-profit projects completed from Jan 2007 through April 2009).
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Solar PV – Commercial Fixed Tilt
Selected Technology Description

In California, the commercial sector leads with installed capacity with 151.1 MW and an average system size of 138 kW.

Typical Plant

Roof Integral Membrane PV Installation – Savoy Building, San Francisco
Source: Applied Solar

Description

- **Photovoltaic (PV) systems** include the PV modules themselves and the Balance of Systems (BOS), including mounting structures, wiring, overcurrent protection and inverters (the electronic device that converts DC to AC electricity).
- **Roof mounting**: One of the most common options, modules can either be installed with specially designed mounting structures or integral to the roof membrane.
- **Ground mounting (fixed tilt):** Should a parcel of land be available, mounting the PV modules on the ground is an option. Fixed tilt structures can be put in place through concrete supports sunk in the ground. Ground mounted structures can be installed in open fields or as part of shade structures.

Solar PV – Commercial Fixed Tilt
Cost Drivers

Solar incentives in California still play a big role in the viability of commercial systems.

Cost Drivers

Key Cost Drivers

- California Solar Initiative Incentives
- Installed Costs – range from $3,000/kW - $16,000/kW, average $7,860/kW
- Capacity Factors – range of 14.1% - 17.5%, with average of 16.2%
- Fixed O&M Costs – range of $25-35/kW-yr, average $30/kW-yr

Plant Configuration Data Overview

Technology Cost Input Data:				
1.0 - Capacity:	**Units**	**Min**	**Average**	**Max**
Capacity Range:	kWe	1.2	138	1200
Average Capacity:	kWe dc		138	
2.0 - Installed Costs:	**Units**	**Min**	**Average**	**Max**
Installed Cost Range:	$/kW	$3,000	$7,860	$16,000
Average Installed Cost:	$/kW		$7,860	
3.0 - Cost Driver and Experience Curve:				
	Units	**Start Year Values**		
		2009	**2015**	**2020**
Technology Progress Ratio:	%/yr	2.2%	2.2%	2.2%
4.0 - Operating Costs and Data:	**Units**	**Min**	**Average**	**Max**
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 25.00	$ 30.00	$ 35.00
Capacity Factor:	%/yr	14.1%	16.2%	17.5%
Annual Operating Hours (calculated):	hr/yr	1,235	1,419	1,533
Outage Rate (%/yr)			2.0%	
Performance Degradation (%/yr)			1.0%	
Transmission Losses (%)			0.0%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-
5.0 - Financial and Investment Data:	**Units**	**Min**	**Average**	**Max**
System Life (years)		20	25	30
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.0%	
Annual Investment Cost (calculated):	$/kW-yr		$865.92	

Solar PV – Commercial Fixed Tilt
Current Costs and Cost Trajectory

Technology advances in PV modules will reduce costs over time.

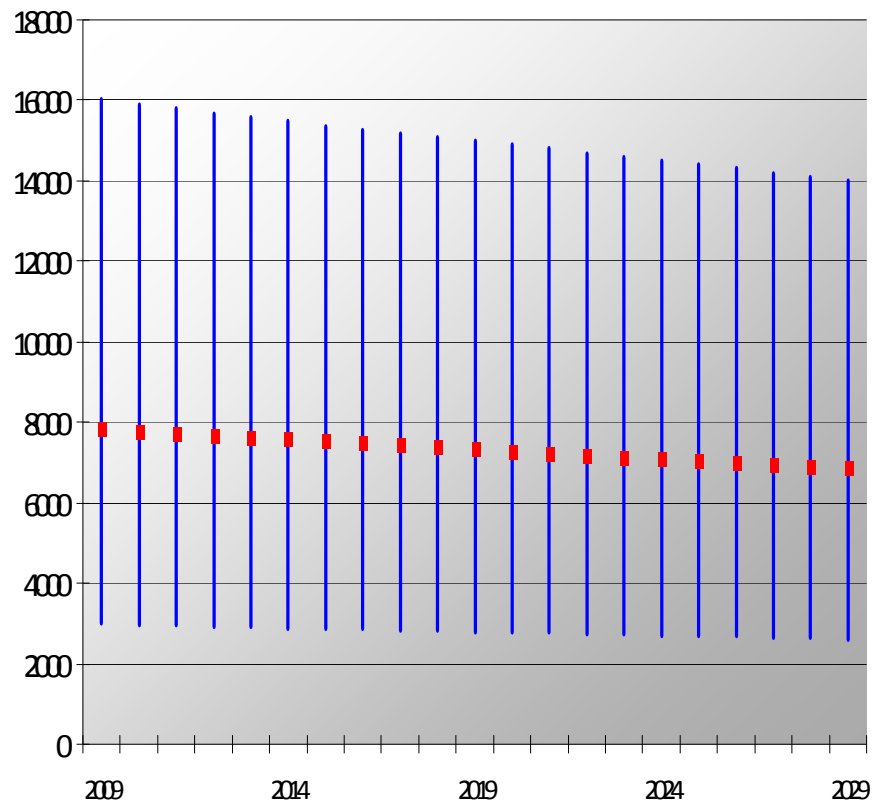
Current Costs

Technology Investment and Energy Costs:

5.0 - Total Investment and Energy Costs: (Output)

		2009
IEPR Price Deflator:		1
Experience Curve Ratio - Installed Cost:		1
Investment Cost Trajectory ($/kW)		**2009**
Installation - Average	$/kW	$7,860
Installation - High	$/kW	$16,000
Installation - Low	$/kW	$3,000
Annual Investment Costs ($/kW-yr):		**2009**
Average	$/kW-yr	$865.92
Fuel, Energy and O&M Costs ($/kW-yr)		**2009**
Fuel Cost - Average	$/kW-yr	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -
Annual O&M Cost - Average	$/kW-yr	$ 30.00
Total Annual Energy Costs:		**2009**
Average	$/kW-yr	**$895.92**
Total Annual Energy Output:		**2009**
Average	kWh/yr	190,003

Installed Cost Projections ($/kW)



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Solar PV – Ground Based Tracking

Wind – Community Scale

Hydroelectric – In Conduit

Integrated Solar Space and Water Heating

Geothermal Heat Pumps

Solar Water Heating - Residential

Solar PV – Ground Based Tracking
Key Cost Influences

Although tracking mechanisms require greater acreage per installed kW than fixed tilt PV, significant increases in electric production result.

Key Cost Influences	**Solar Photovoltaic – Ground Based Tracking** **Capacity Factor**: From the California SGIP in 2006, the annual weighted average capacity factor was determined to be 16.2%. This results in a range of 14.1%-17.5%. Annual capacity factor increases by 30% with trackers when averaged over the various California locations included in NREL's Red Book. This results in a range of 18.3%-23.0%, with average CF of 21.0%. **Installed Cost:** Single Axis tracker costs add $1,000/kW to overall installed cost, with range of $5,500 – $10,500/kW, averaging $7,340/kW. A wide spread of installed costs exist, representing the wide variation in applications. **Fixed O&M**: Fixed O&M is very similar to that for flat plate PV. The main difference is the tracking mechanism. Single-axis tracking systems tend to be larger than roof-top mounted, requiring more effort (and expense) to ensure maintenance staff availability should the system go down or perform sub-optimally.
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Solar PV – Ground Based Tracking
Selected Technology Description

Significant benefits can be derived from tracking systems under the California Solar Initiative (CSI) performance-based incentives.

Typical Plant	Description
 Ground-based Solar PV System with Trackers Nellis AFB, NV Source: SunPower Corporation	Ground mounting structures can include *trackers* that follow the sun's path throughout the day. A single axis tracker simply tilts from east to west, following the sun's path throughout the day. Photovoltaic (PV) systems include the PV modules themselves and the Balance of Systems (BOS). The BOS includes mounting structures, wiring, overcurrent protection and inverters (the electronic device that converts DC to AC electricity).

Solar PV – Ground Based Tracking
Cost Drivers

Tracking costs are similar to flat-plate PV, with the added cost of the tracker. Sun tracking improves capacity factor by approximately 30% in California.

Cost Drivers

Key Cost Drivers

- California Solar Initiative Incentives
- Installed Costs – range from $5,500/kW - $10,500/kW, average $7,340/kW
- Capacity Factors – range of 18.3% - 23.0%, with average of 21.0%
- Fixed O&M Costs – range of $60-92/kW-yr, average $68/kW-yr
- Geography and solar radiation potential (Palm Springs vs. San Francisco)

Plant Configuration Data Overview

Technology Cost Input Data:				
1.0 - Capacity:	**Units**	**Min**	**Average**	**Max**
Capacity Range:	kWe	500	1500	3000
Average Capacity:	kWe dc		1500	
2.0 - Installed Costs:	**Units**	**Min**	**Average**	**Max**
Installed Cost Range:	$/kW	$5,500	$7,340	$10,500
Average Installed Cost:	$/kW		$7,340	
3.0 - Cost Driver and Experience Curve:				
	Units	**Start Year Values**		
		2009	**2015**	**2020**
Technology Progress Ratio:	%/yr	2.2%	2.2%	2.2%
4.0 - Operating Costs and Data:	**Units**	**Min**	**Average**	**Max**
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 60.00	$ 68.00	$ 92.00
Capacity Factor:	%/yr	18.3%	21.0%	23.0%
Annual Operating Hours (calculated):	hr/yr	1,603	1,840	2,015
Outage Rate (%/yr)			2.0%	
Performance Degradation (%/yr)			1.0%	
Transmission Losses (%)			0.5%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-
5.0 - Financial and Investment Data:	**Units**	**Min**	**Average**	**Max**
System Life (years)		20	25	30
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.0%	
Annual Investment Cost (calculated):	$/kW-yr		$808.63	

Solar PV – Ground Based Tracking
Current Cost and Cost Trajectory

System costs are expected to decline 2.2% per year due to scale economies and increased learning effect from installations.

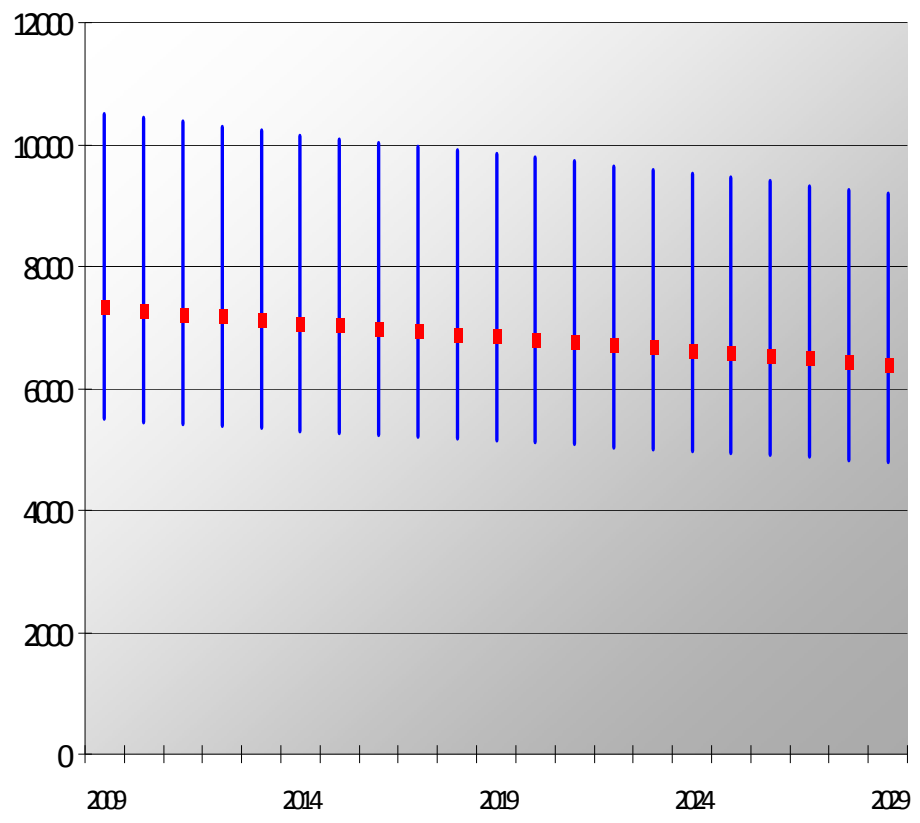
Current Costs

Technology Investment and Energy Costs:

5.0 - Total Investment and Energy Costs: (Output)

		2009
IEPR Price Deflator:		1
Experience Curve Ratio - Installed Cost:		1
Investment Cost Trajectory ($/kW)		**2009**
Installation - Average	$/kW	$7,340
Installation - High	$/kW	$10,500
Installation - Low	$/kW	$5,500
Annual Investment Costs ($/kW-yr):		**2009**
Average	$/kW-yr	$808.63
Fuel, Energy and O&M Costs ($/kW-yr)		**2009**
Fuel Cost - Average	$/kW-yr	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -
Annual O&M Cost - Average	$/kW-yr	$ 68.00
Total Annual Energy Costs:		**2009**
Average	$/kW-yr	**$876.63**
Total Annual Energy Output:		**2009**
Average	kWh/yr	2,663,784

Installed Cost Projections ($/kW)



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Solar PV – Ground Based Tracking

Wind – Community Scale

Hydroelectric – In Conduit

Integrated Solar Space and Water Heating

Geothermal Heat Pumps

Solar Water Heating - Residential

Wind – Community Scale
Key Cost Influences

The main drivers are energy output (driven by capacity factor) and equipment costs (approximately 75% of total system costs)

Key Cost Influences	**Community Scale Wind** **Capacity Factor:** Varies dramatically on the location (optimal site selection), turbine size and tower height. Capacity factors have been increasing in recent years, but can generally range from 12% to 37% with an assumed average of 25%. **Equipment costs:** Wind turbine costs have been steadily increasing since 2002 mainly due to a combination of market effects; for example increased cost of raw materials (copper, steel, etc), exchange rates between the US dollar and the Euro and shortages of certain turbine components. Some of these market effects have shown reversals within the past two years.
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Wind – Community Scale
Selected Technology Description

The term "community wind" refers to the method and intention of development. Local community members own and have a financial stake in the project.

Typical Plant	Description
 Source: windustry.org	Parameters vary somewhere between small building scale wind and utility scale wind. Generally, community wind capacities can range from 100 kW to 10 MW, although there is no consistent size range defined. Locally owned by farmers, investors, businesses, schools, utilities or other public or private entities.

Wind – Community Scale
Cost Drivers

Overall cost of generation is expected to fall between those for utility scale and building scale wind

Cost Drivers

Key Cost Drivers

- Cost of electricity
- Turbine cost (typically 75% of total cost)
- Wind class and site topography - drives capacity factor. Communities are often located where the wind is low.

Plant Configuration Data Overview

Technology Cost Input Data:

1.0 - Capacity:	Units	Min	Average	Max
Capacity Range:	kWe	100	5000	10000
Average Capacity:	kWe dc		5000	

2.0 - Installed Costs:	Units	Min	Average	Max
Installed Cost Range:	$/kW	$2,000	$2,500	$4,000
Average Installed Cost:	$/kW		$2,500	

3.0 - Cost Driver and Experience Curve:	Units	Start Year Values		
		2009	2015	2020
Technology Progress Ratio:	%/yr	0.5%	0.5%	0.5%

4.0 - Operating Costs and Data:	Units	Min	Average	Max
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 15.00	$ 26.00	$ 42.00
Capacity Factor:	%/yr	12.0%	25.0%	37.0%
Annual Operating Hours (calculated):	hr/yr	1,051	2,190	3,241
Outage Rate (%/yr)			4.0%	
Performance Degradation (%/yr)			1.0%	
Transmission Losses (%)			2.5%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-

5.0 - Financial and Investment Data:	Units	Min	Average	Max
System Life (years)		15	20	25
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.7%	
Annual Investment Cost (calculated):	$/kW-yr		$293.65	

Wind – Community Scale
Current Cost and Cost Trajectory

Wind cost trajectories are expected to show moderate learning effects with some overall increases based on inflation

Current Costs

Technology Investment and Energy Costs:
6.0 - Total Investment and Energy Costs: (Output)

		2009
IEPR Price Deflator:		1
Experience Curve Ratio - Installed Cost:		1

Investment Cost Trajectory ($/kW)		2009
Installation - Average	$/kW	$2,500
Installation - High	$/kW	$4,000
Installation - Low	$/kW	$2,000

Annual Investment Costs ($/kW-yr):		2009
Average	$/kW-yr	$293.65

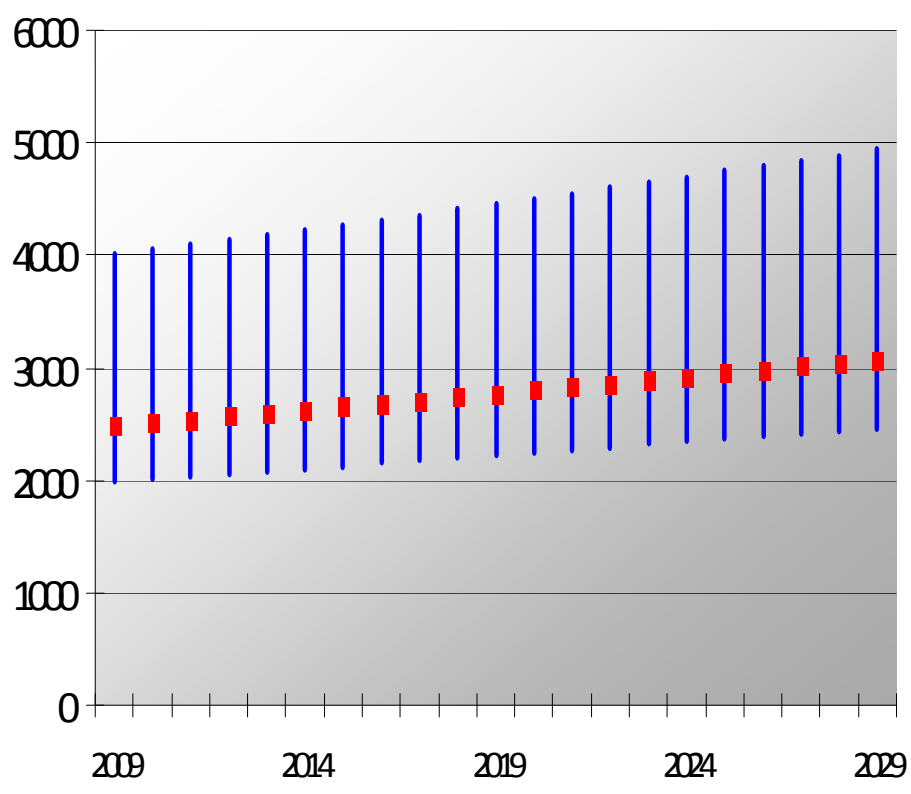
Fuel, Energy and O&M Costs ($/kW-yr)		2009
Fuel Cost - Average	$/kW-yr	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -
Annual O&M Cost - Average	$/kW-yr	$ 26.00

Total Annual Energy Costs:		2009
Average	$/kW-yr	**319.65**

Total Annual Energy Output:		2009
Average	kWh/yr	10,146,708

Total Output Through System Life:		Total
Average	kWh	193,063,576

Installed Cost Projections ($/kW)



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Hydroelectric – In Conduit

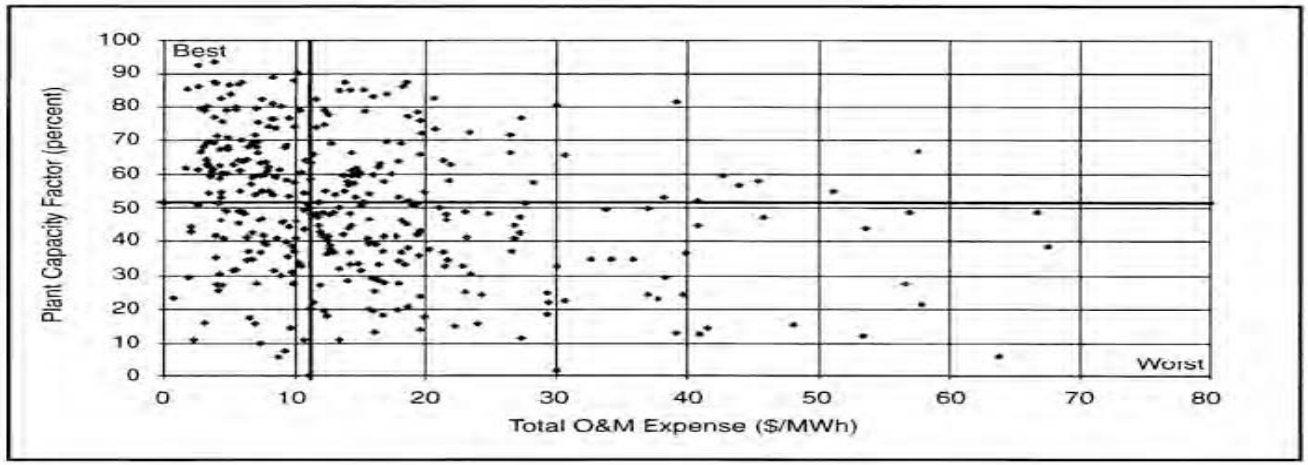
Integrated Solar Space and Water Heating

Geothermal Heat Pumps

Solar Water Heating - Residential

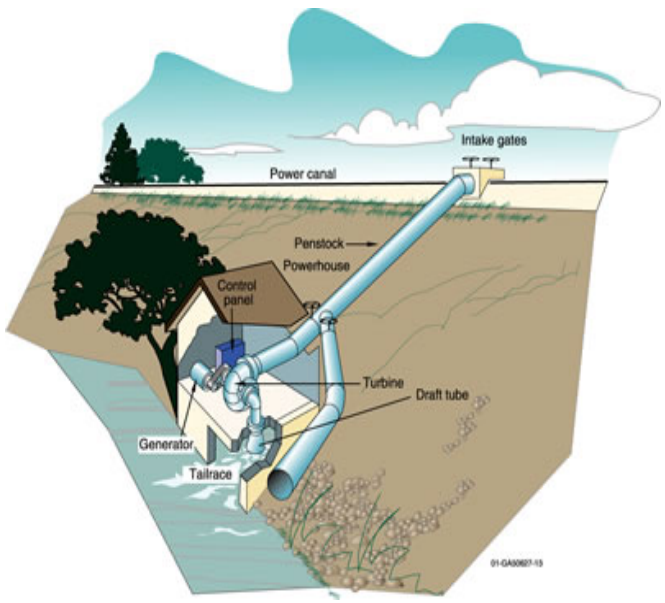
Hydroelectric – In Conduit
Key Cost Influences

Varying water flows cause widely spread capacity factors

Key Cost Influences	**<u>In Conduit Hydro:</u>** **<u>Capacity factors and O&M Expenses</u>** are highly variable depending on turbine efficiency and variability in feet of head, flow rate and seasonal usage. Irrigation districts in northern climates will typically have a shorter irrigation season than in southern climates. Municipal water districts may shut down the hydro facility for one month a year for maintenance. 
	Reference Material: see "<u>Task 1- Central Plant Technologies.xls</u>"

Hydroelectric – In Conduit
Selected Technology Description

Technical potential for up to 255 MW of generation capacity in California from in-conduit hydropower facilities.

Typical Plant	Description
 In Conduit Hydroelectric Schematic Source: INEL	• Community scale hydropower is considered to be from man-made conduits (canals, irrigation ditches, aqueducts, pipelines, etc) from municipal water agencies and irrigation districts. • Electric out put of this technology is dependent on water flow rate and pressure (ft of head). • Two Main Types of Turbines Used: — **Impulse** - Uses the velocity of water to move the runner and discharges to atmospheric pressure. — **Reaction** - Develops power from the combined action of pressure and moving water.

Hydroelectric – In Conduit
Cost Drivers

Hydropower is a mature technology in operation for over a century – no significant learning curve effects are expected

Cost Drivers

Key Cost Drivers

- Unit Capacity Factor – varies due to season, head, flowrates
- Fixed O&M Costs – vary widely from $12/MWh to $105/MWh
- Outage Rates – due to seasonal use
- Transmission Line Cost
- Site Feasibility Study
- Capital Cost – range $1,156/kW to $3,853/kW, average $1,968/kW

Plant Configuration Data Overview

Technology Cost Input Data:

1.0 - Capacity:	Units	Min	Average	Max
Capacity Range:	kWe	100	1100	3000
Average Capacity:	kWe dc		1100	

2.0 - Installed Costs:	Units	Min	Average	Max
Installed Cost Range:	$/kW	$1,156	$1,968	$3,853
Average Installed Cost:	$/kW		$1,968	

3.0 - Cost Driver and Experience Curve:	Units	Start Year Values		
		2009	2015	2020
Technology Progress Ratio:	%/yr	1.5%	1.5%	1.5%

4.0 - Operating Costs and Data:	Units	Min	Average	Max
Average O&M Costs ($/kW/yr)	$/kW-yr	$ 12.00	$ 59.50	$ 105.00
Capacity Factor:	%/yr	10.0%	51.0%	90.0%
Annual Operating Hours (calculated):	hr/yr	876	4,468	7,884
Outage Rate (%/yr)			0.0%	
Performance Degradation (%/yr)			2.0%	
Transmission Losses (%)			5.0%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-

5.0 - Financial and Investment Data:	Units	Min	Average	Max
System Life (years)		20	25	30
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.0%	
Annual Investment Cost (calculated):	$/kW-yr		$216.81	

Hydroelectric – In Conduit
Current Cost and Cost Trajectory

Hydroelectric is a mature industry. Moderate learning effects could be offset by inflation.

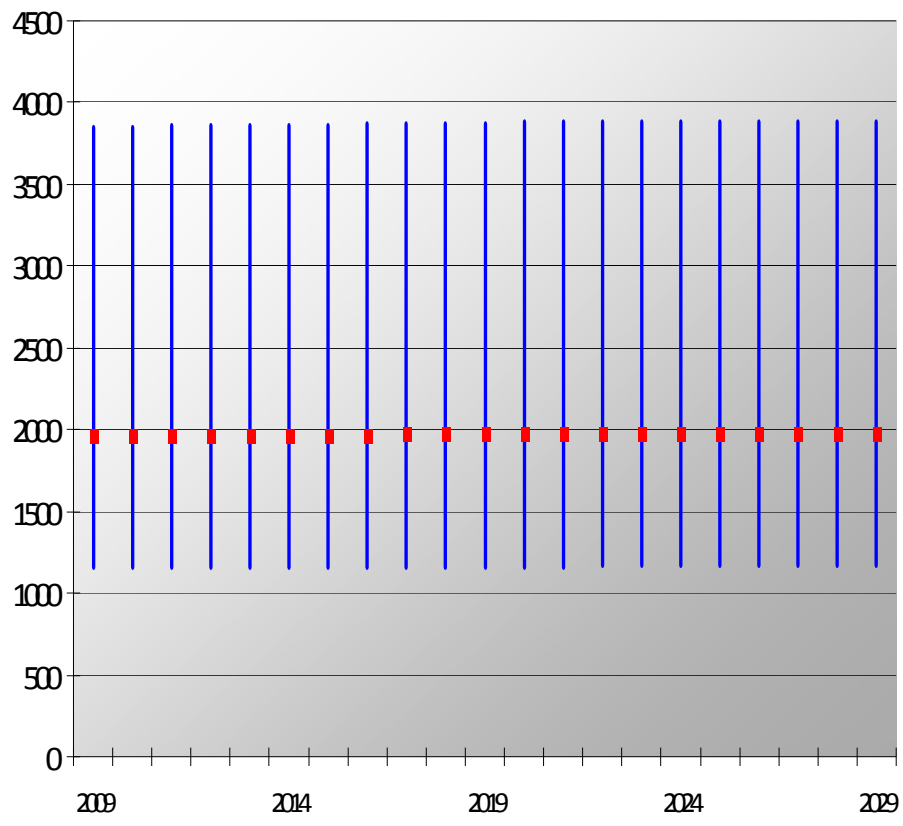
Current Costs

Technology Investment and Energy Costs:

5.0 - Total Investment and Energy Costs: (Output)

		2009
IEPR Price Deflator:		1
Experience Curve Ratio - Installed Cost:		1
Investment Cost Trajectory ($/kW)		**2009**
Installation - Average	$/kW	$1,968
Installation - High	$/kW	$3,853
Installation - Low	$/kW	$1,156
Annual Investment Costs ($/kW-yr):		**2009**
Average	$/kW-yr	$216.81
Fuel, Energy and O&M Costs ($/kW-yr)		**2009**
Fuel Cost - Average	$/kW-yr	$ -
Auxiliary Energy Cost - Average	$/kW-yr	$ -
Annual O&M Cost - Average	$/kW-yr	$ 59.50
Total Annual Energy Costs:		**2009**
Average	$/kW-yr	**276.31**
Total Annual Energy Output:		**2009**
Average	kWh/yr	4,575,269

Installed Cost Projections ($/kW)



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Hydroelectric – In Conduit

Integrated Solar Space and Water Heating

Geothermal Heat Pumps

Solar Water Heating - Residential

Integrated Solar Space and Water Heating
Key Cost Influences

Integrated Solar can reduce natural gas and electricity use in California, contributing to energy efficiency, security, and climate action goals.

Key Cost Influences	**Integrated Solar Space and Water Heating:** **Solar Collection Area**: Capital cost is determined primarily by the solar collection area needed to heat water in the system. **Community-Scale Costs Can Be High**: Developers for Drake Landing estimate the cost for delivering heat is about $23 million/MMBtu. In addition, specific analysis must be done for each community to understand costs and economics. **New Building or Retrofit**: It is difficult and costly to retrofit existing building structures with integrated solar technologies. Best cost efficiencies are achieved during re-roofing installations where the energy savings can help pay for roof installation. **Natural Gas Price**: Sets the economic switch point between integrated solar technologies and conventional natural gas heating which is prevalent in California. **Scale**: Currently, most systems are sized for residential and small commercial applications (80-120 gallon tank size). Larger commercial applications either bundle modules, or use custom-designed tank systems.
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Integrated Solar Space and Water Heating
Selected Technology Description

Reducing natural gas consumption for heating in California, integrated solar heating technologies are useful for commercial buildings and pool heating.

Typical Plant

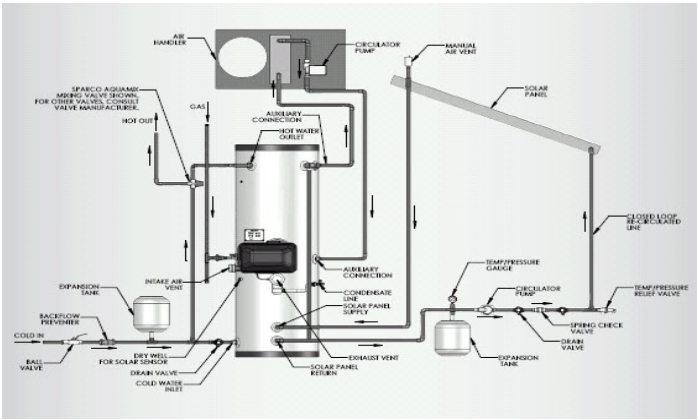


Photo credit: STS Solar, American Solar, FL Solar Energy Ctr.

Description

1) Fluidic System

Sunlight-absorbing solar collector arrays are used to heat water (or glycol) to 60-80 deg.F above ambient temperature.

This hot water is piped through a thermal circuit similar to a hot water heater tank, where it is used to circulate hot water for domestic uses as well as space heating.

2) Air System

An air system uses light-absorbing metal roof or building panels to heat air to 80 deg. F above ambient temperature.

This air is used for space heating and preheating of water.

Integrated Solar Space and Water Heating Cost Drivers

Integrated solar heating and cooling technologies are disadvantaged by a fragmented supplier business model. Better integration will drive success.

Cost Drivers

Key Cost Drivers

- Usage Application
- Scale (overall thermal load) – most systems are small-scale, sized for residential and small commercial applications.
- Degree of building retrofit
- Solar collection system area
- Roof-type
- Roof Area
- Climate Zone
- Industry Fragmentation – current market makers are fragmented between roofing/siding installers, HVAC firms, and heating equipment manufacturers.
- Limited Standards Exist for Equipment, Safety, Performance Certifications – required for CSI incentives in California.

Plant Configuration Data Overview

Technology Cost Input Data:

1.0 - Capacity:	Units	Min	Average	Max
Capacity Range:	kW th	3.5	14	25
Average Capacity:	kW th		14	

2.0 - Installed Costs: (per solar area)	Units	Min	Average	Max
Installed Cost Range:	$/kW th	$1,300	$1,950	$2,925
Average Installed Cost:	$/kW th		$1,950	

3.0 - Cost Driver and Experience Curve:	Units	Start Year Values			
		2009	2015	2020	2029
Technology Progress Ratio:	%/yr	1.5%	4.0%	4.0%	1.5%

4.0 - Operating Costs and Data:	Units	Min	Average	Max
Average O&M Costs ($/kWth-yr)	$/kWth-yr	$ 117.00	$ 175.00	$ 263.00
Capacity Factor:	%/yr	24.0%	34.0%	39.0%
Annual Operating Hours (calculated):	hr/yr	2,102	2,978	3,416
Outage Rate (%/yr)			0.2%	
Performance Degradation (%/yr)			0.0%	
Transmission Losses (%)			0.0%	
Auxiliary Energy Costs	$/kWth-yr	-	-	-
Fuel Costs:	$/yr	-	-	-

5.0 - Financial and Investment Data:	Units	Min	Average	Max
System Life (years)		8	20	30
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.7%	
Annual Investment Cost (calculated):	$/kW-yr		$229.05	

Integrated Solar Space and Water Heating
Current Cost and Cost Trajectory

Industry sources say <u>at least</u> 5 years to begin any scale effects.

Current Costs

Technology Investment and Energy Costs:

3.0 - Total Investment and Energy Costs: (Output)

		2009	2010	2011
IEPR Price Deflator:		1	1.01488202	1.031200964
Experience Curve Ratio - Installed Cost:		1	0.985000	0.970225

Investment Cost Trajectory		2009	2010	2011
Installation - Average	$/kWth-yr	$1,950	$1,949	$1,951
Installation - High	$/kWth-yr	$2,925	$2,924	$2,926
Installation - Low	$/kWth-yr	$1,300	$1,300	$1,301

Annual Investment Costs ($/kW-yr):		2009	2010	2011
Average	$/kWth-yr	$229.05	$228.97	$229.16

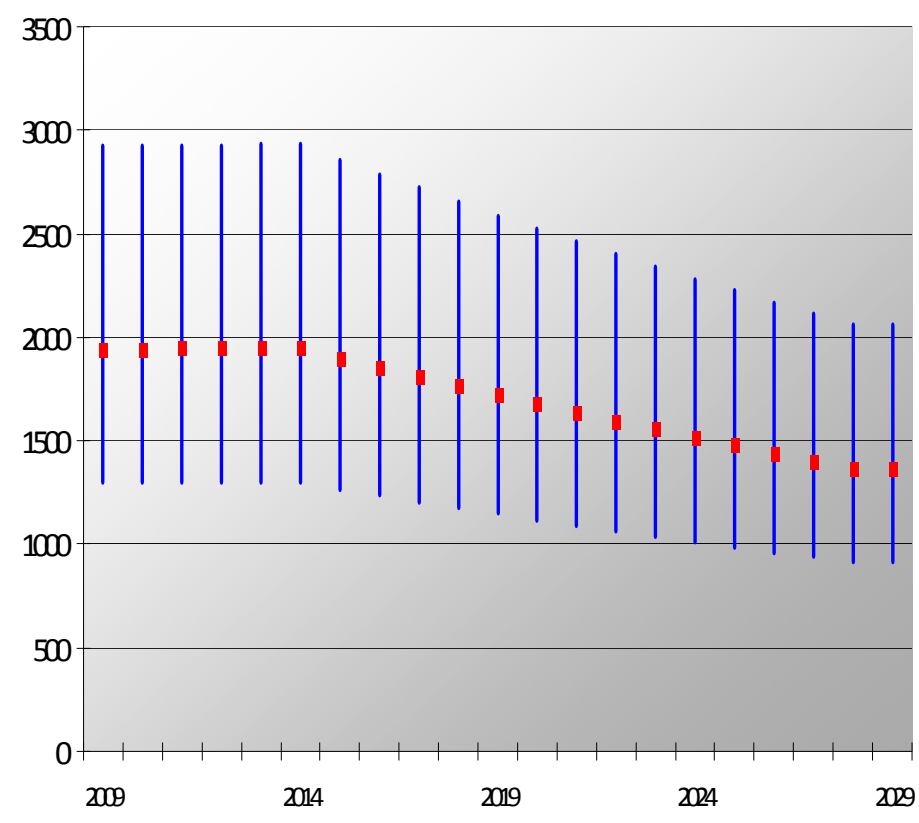
Fuel, Energy and O&M Costs ($/kW-yr)		2009	2010	2011
Fuel Cost - Average	$/kWth-yr	$ -	$ -	$ -
Auxiliary Energy Cost - Average	$/kWth-yr	$ -	$ -	$ -
Annual O&M Cost - Average	$/kWth-yr	$ 175.00	$ 177.60	$ 180.46

Total Annual Energy Costs:		2009	2010	2011
Average	$/kWth-yr	**404.05**	**406.57**	**409.62**

Total Annual Energy Output:		2009	2010	2011
Average	kWh th/yr	41,614	41,614	41,614

Total Output Through System Life:		Total
Average	kWh	873,898

Installed Cost Projections ($/kW)



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Building and Community Scale – Technology and Cost Profiles

Approach and Methodology

Biomass – Advanced Digester Food Industry (Biogas)

Biomass – Landfill Gas (LFG)

Biomass – Waste Water Treatment Plant

Solar Photovoltaic (PV) – Residential and Commercial Fixed Tilt

Solar PV – Ground Based Tracking

Wind – Community Scale

Hydroelectric – In Conduit

Integrated Solar Space and Water Heating

Geothermal Heat Pumps

Solar Water Heating - Residential

Geothermal Heat Pumps
Key Cost Influences

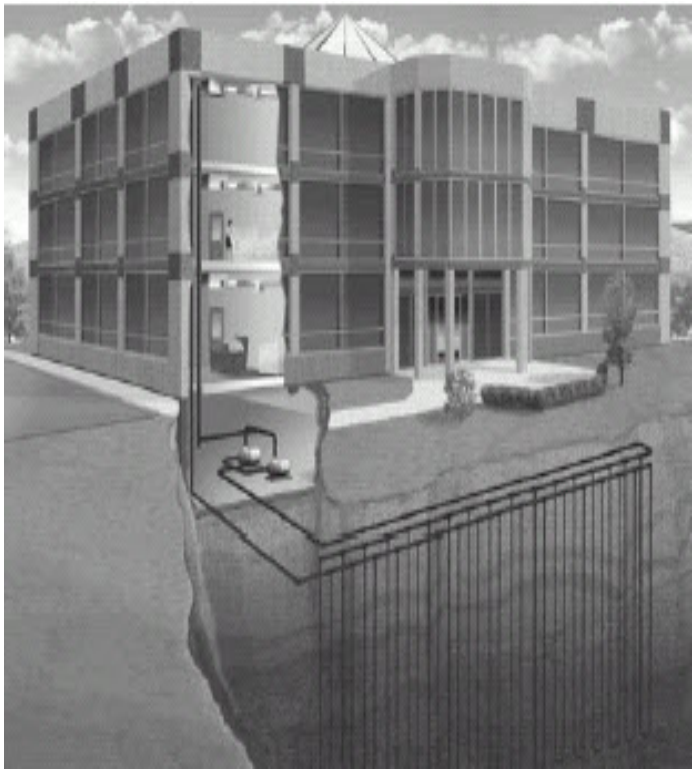
Utilities state that the primary barrier to geothermal heat pumps is the incremental cost of installing the ground loop.

Key Cost Influences	**Geothermal Heat Pumps:** **Ground Loop Installation Costs**: Depending on the soil type and number of drilling contractors in an area, drilling costs range from $5.00/bore foot to $20.00/bore foot. ($900 – 1300/design ton) **Building Design Loads and Use**: For geothermal, it is important to consider both the building loads and use, as the type of use helps determine seasonal heating and cooling balance in equivalent full load operating hours (EFLH) and sets the size of the ground loop. **Maintenance**: Geothermal system maintenance for central systems is a low influence on cost, due to the reliability inherent in the ground loop, and lack of cooling tower equipment. Maintenance costs average $0.17/sq.ft.-yr. **Soil Thermal Conductivity**: Soil heat transfer characteristics have a unique, site-specific effect on overall system costs. Maximizing soil conductivity minimizes ground loop size and cost. Current practice uses engineering software tools and soil testing to optimize ground loop size and cost. **Pumping Costs**: Compared to conventional cooling tower HVAC systems, pumping costs are significantly lower. **Water scaling potential**: Even small amounts of water scale can significantly erode performance and efficiency.
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Geothermal Heat Pumps
Selected Technology Description

While higher in initial capital cost than other commercial HVAC systems, geothermal heat pumps offer significant reductions in overall energy use.

Typical Plant



Vertical Ground Bore Geothermal System
Source: McQuay International

Description

Geothermal Heat Pump Systems:

- Couple the building to the local environment
- Use ground as a constant temperature reservoir for heat pump operation
- Because of the constant temperature, heat pumps operate more efficiently saving energy
- Long-life and reliable operation

Main System Types:

- Vertical Ground Loop (most commercial)
- Horizontal Loop (small commercial, residential)
- Pond and Water Source (using water as the thermal reservoir)
- Open Loop (surface water directly in system)

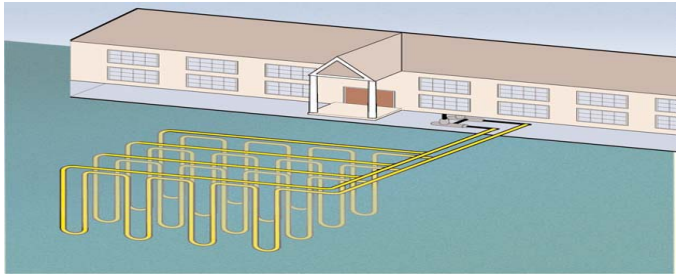
Geothermal Heat Pumps
Cost Drivers

Many variables exist in evaluating geothermal heat pump systems, making a detailed engineering and economic analysis essential for each site.

Cost Drivers

Key Cost Drivers

- Initial Capital Cost
- Thermal Ground Loop Well-field Size (area and number of wells drilled)
- Building Use (office, commercial, hotel, hospital, industrial)
- System Type (ground source, water source, direct coupled, indirect coupled)
- Water Scaling Potential
- Soil Thermal Conductivity (systems >20 tons)
- Ground Loop Pumping Costs
- Limited number of skilled installers



Plant Configuration Data Overview

Technology Cost Input Data:				
1.0 - Capacity:	**Units**	**Min**	**Average**	**Max**
Capacity Range:	tons	50	150	500
Average Capacity:	tons		150	
2.0 - Installed Costs:	**Units**	**Min**	**Average**	**Max**
Installed Cost Range:	$/ton	$1,190	$4,200	$7,300
Average Installed Cost:	$/ton		$4,200	
3.0 - Cost Driver and Experience Curve:				
	Units	**Start Year Values**		
		2009	**2015**	**2020**
Technology Progress Ratio:	%/yr	0.0%	0.0%	0.0%
4.0 - Operating Costs and Data:	**Units**	**Min**	**Average**	**Max**
Average O&M Costs ($/kW/yr)	$/ton-yr	$ 2.60	$ 37.40	$ 112.00
Capacity Factor:	%/yr	98.2%	98.2%	98.2%
Annual Operating Hours (calculated):	hr/yr	8,602	8,602	8,602
Outage Rate (%/yr)			0.2%	
Performance Degradation (%/yr)			0.0%	
Transmission Losses (%)			0.0%	
Auxiliary Energy Costs	$/kW-yr	2.00	2.00	2.00
Fuel Costs:	$/yr	-	-	-
5.0 - Financial and Investment Data:	**Units**	**Min**	**Average**	**Max**
System Life (years)		20	22	25
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.4%	
Annual Investment Cost (calculated):	$/ton-yr		$478.82	

Geothermal Heat Pumps
Current Cost and Cost Trajectory

Average energy cost energy lower than conventional HVAC systems, but higher capital cost. Education and market incentives are essential.

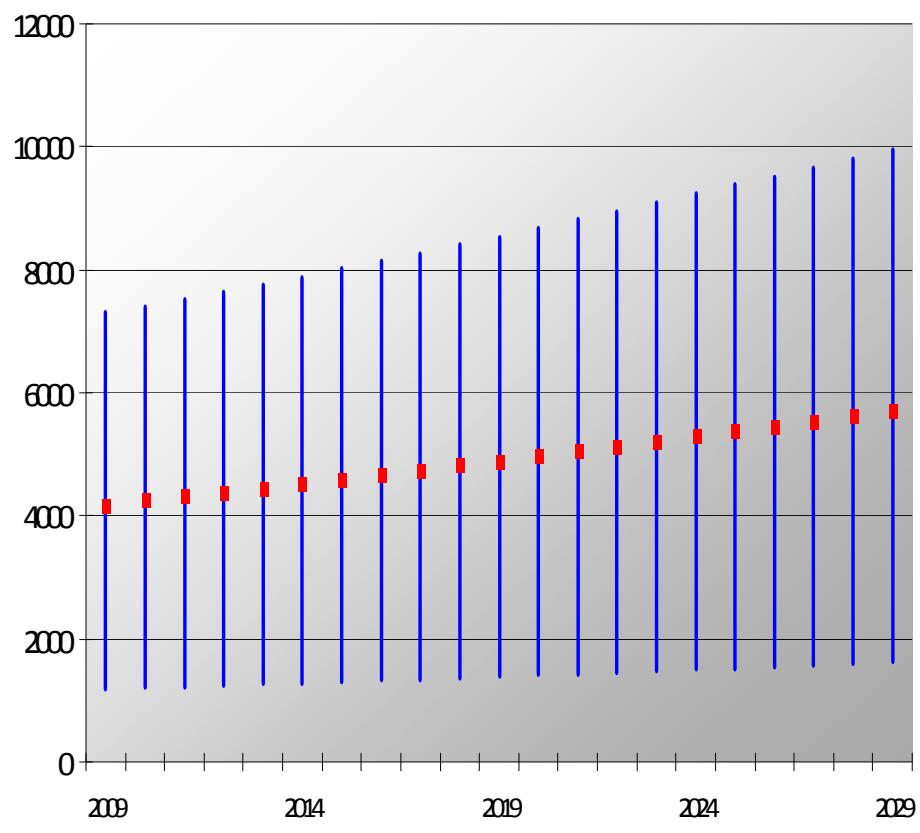
Current Costs

Technology Investment and Energy Costs:

5.0 - Total Investment and Energy Costs: (Output)

		2009
IEPR Price Deflator:		1
Experience Curve Ratio - Installed Cost:		1
Investment Cost Trajectory ($/kW)		**2009**
Installation - Average	$/ton	$4,200
Installation - High	$/ton	$7,300
Installation - Low	$/ton	$1,190
Annual Investment Costs ($/kW-yr):		**2009**
Average	$/ton-yr	$478.82
Fuel, Energy and O&M Costs ($/kW-yr)		**2009**
Fuel Cost - Average	$/ton-yr	$ -
Auxiliary Energy Cost - Average	$/ton-yr	$ 0.04
Annual O&M Cost - Average	$/ton-yr	$ 37.40
Total Annual Energy Costs:		**2009**
Average	$/ton-yr	**516.26**
Total Annual Energy Output:		**2009**
Average	tons/yr	1,287,767

Installed Cost Projections ($/kW)



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Integrated Solar Space and Water Heating

Geothermal Heat Pumps

Solar Water Heating - Residential

Solar Water Heating - Residential
Key Cost Influences

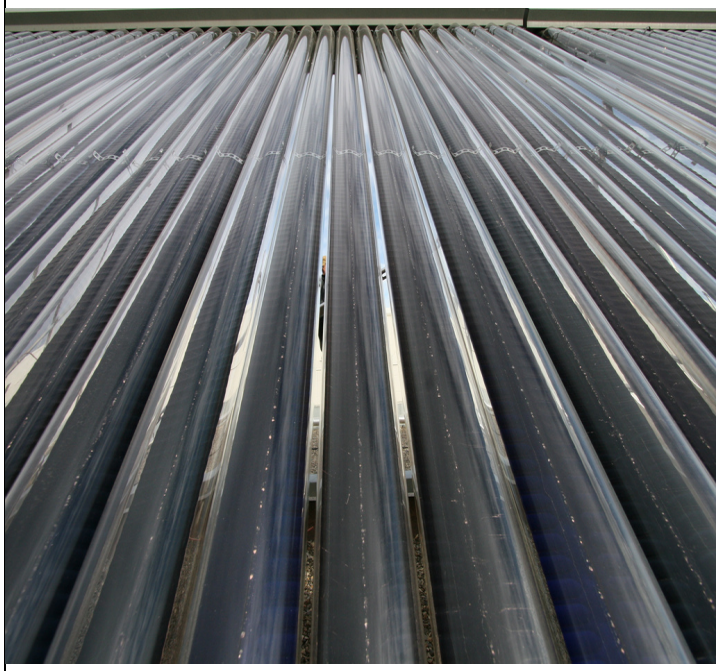
Much of the contractor expertise in solar hot water system installation in California has disappeared since the 1980's.

Key Cost Influences	**Solar Water Heating - Residential:** **AB1470 Incentives**: Potentially establishing a market for residential solar water heating resulting in scale economies and market penetration. **Solar Collection Area**: Capital cost is determined primarily by the solar collection area needed to heat water in the system. **New Home or Retrofit**: Integrated roofing designs have potential for reducing costs. **Natural Gas Price**: Sets the economic switch point between integrated solar technologies and conventional natural gas heating which is prevalent in California. **Installed Market**: Growth in residential installations will lead to a robust network of industry suppliers and reduction in overall installed cost. Better and more complete contractor integration will also drive costs down. **DOE Research Funding**: Goal to reduce solar hot water installation costs by 50%. **Equipment Costs**: Raw material costs, such as aluminum and copper commodity escalation, in addition to fuel costs for shipping.
	Reference Material: see "Task 1- Central Plant Technologies.xls"

Solar Water Heating - Residential
Selected Technology Description

Solar thermal water heating offers tremendous untapped potential in California.

Typical Plant



Residential Evacuated-Tube Solar Heat Array
Source: Aztec Solar Water Heaters, UK

Description

- **Integrated collector-storage (ICS)** – passive systems using solar thermal collectors integrated with storage tanks.
- **Thermosyphon** – passive system where the solar thermal collector is installed at a lower elevation than the storage tank. The collector heats water which rises to the tank.
- **Drainback** – Pump circulates water or an anti-freeze solution through the system during the day, but shuts down at night, thus allowing the fluid to drain back into a storage tank. Offers freeze protection.
- **Glycol Active** – This is a closed loop system that circulates an anti-freeze solution through the solar thermal collector and heat exchanger.
- **Direct Forced Circulation** – An open loop system which circulates the water directly through the solar thermal collectors and into a storage tank.

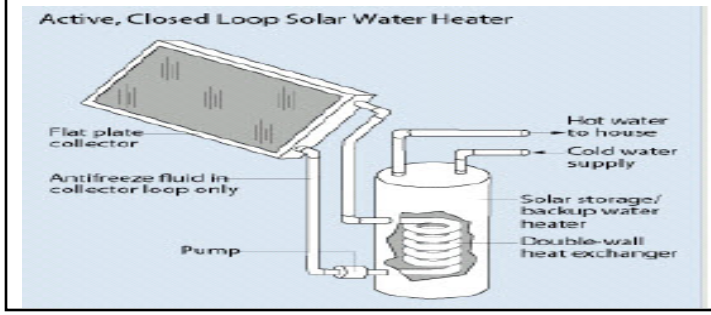
Solar Water Heating - Residential
Cost Drivers

Solar hot water heating incentives in California are projected to lower the overall cost of this technology through increased market penetration

Cost Drivers

Key Cost Drivers

- Energy Savings versus Existing Hot Water Technologies
- State Incentive Programs
- Fixed O&M – range $25-40/year, averaging $30/year
- Equipment Cost (57% of total)
- Installation Labor (23% of total)
- Capacity Degradation – due to fouling, sediment or corrosion, 0.5%/year



Plant Configuration Data Overview

Technology Cost Input Data:				
1.0 - Capacity:	**Units**	**Min**	**Average**	**Max**
Capacity Range:	kWe	1	1	1
Average Capacity:	kWe dc		1	
2.0 - Installed Costs:	**Units**	**Min**	**Average**	**Max**
Installed Cost Range:	$/system	$3,000	$6,542	$11,500
Average Installed Cost:	$/system		$6,542	
3.0 - Cost Driver and Experience Curve:				
	Units	**Start Year Values**		
		2009	**2015**	**2020**
Technology Progress Ratio:	%/yr	1.5%	4.0%	4.0%
4.0 - Operating Costs and Data:	**Units**	**Min**	**Average**	**Max**
Average O&M Costs ($/kW/yr)	$/system-yr	$ 25.00	$ 30.00	$ 40.00
Savings	Therms/yr	88	116	133
Annual Operating Hours (calculated):	hr/yr	-	-	-
Outage Rate (%/yr)			0.0%	
Performance Degradation (%/yr)			0.5%	
Transmission Losses (%)			0.0%	
Auxiliary Energy Costs	$/kW-yr	-	-	-
Fuel Costs:	$/yr	-	-	-
5.0 - Financial and Investment Data:	**Units**	**Min**	**Average**	**Max**
System Life (years)		15	20	25
Interest Rate:	%/yr		10.0%	
Annuity Factor: (calculated):	-		11.7%	
Annual Investment Cost (calculated):	$/kW-yr		$768.42	

Solar Water Heating - Residential
Current Cost and Cost Trajectory

The DOE is providing R&D funding to reduce the cost of installed solar hot water systems by 50%.

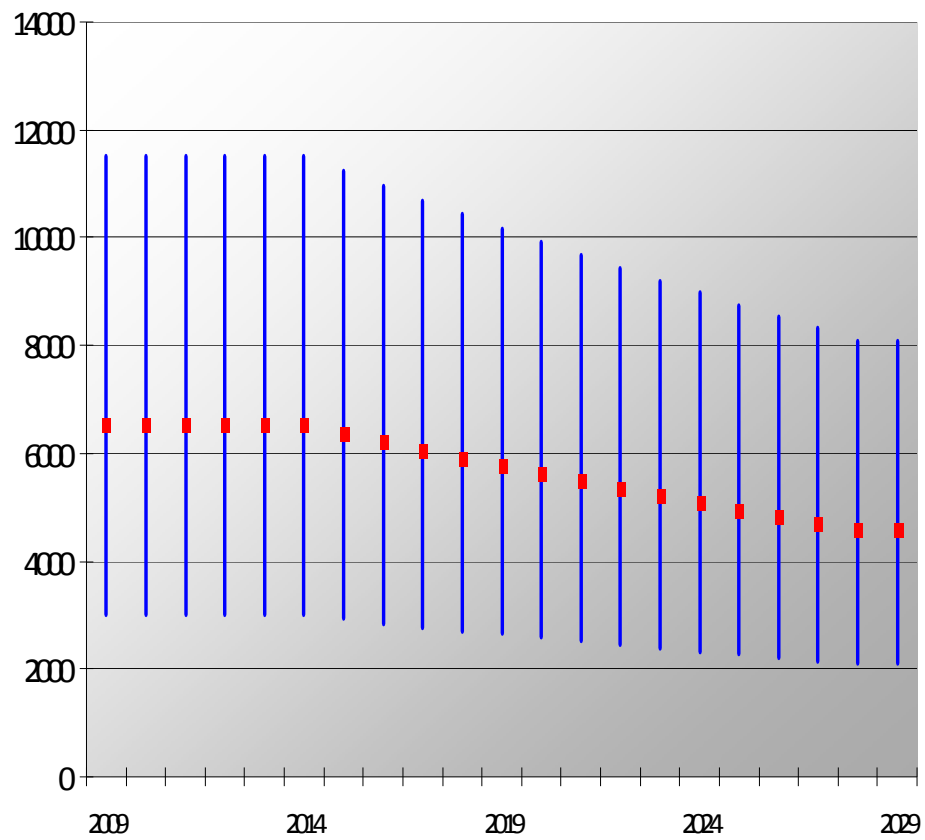
Current Costs

Technology Investment and Energy Costs:

5.0 - Total Investment and Energy Costs: (Output)

		2009
IEPR Price Deflator:		1
Experience Curve Ratio - Installed Cost:		1
Investment Cost Trajectory ($/system)		**2009**
Installation - Average	$/system	$6,542
Installation - High	$/system	$11,500
Installation - Low	$/system	$3,000
Annual Investment Costs ($/system-yr):		**2009**
Average	$/system-yr	$768.42
Fuel, Energy and O&M Costs ($/kW-yr)		**2009**
Fuel Cost - Average	$/system-yr	$ -
Auxiliary Energy Cost - Average	$/system-yr	$ -
Annual O&M Cost - Average	$/system-yr	$ 30.00
Total Annual Energy Costs:		**2009**
Average	$/system-yr	**798.42**
Total Annual Energy Savings:		**2009**
Average	Therms/yr	116

Installed Cost Projections ($/system)



Conclusion

Thank you for your attention.

QUESTIONS?