Thermal Energy Storage

Compliance Option

STAFF DRAFT REPORT

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ABSTRACT

This draft Staff Report on *Thermal Energy Storage Systems* describes the impacts that were evaluated by the Commission in determining whether compliance credit with the *2005 Building Energy Efficiency Standards* should be approved. The impacts that are addressed include energy use, emissions, and compliance credit. The report also includes eligibility criteria and acceptance requirements that must be met by contractors to qualify these systems for compliance credit. This report also includes the compliance forms that must be used for reporting to the building departments.

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EXECUTIVE SUMMARY

Staff has prepared this report evaluating an application for approval of a compliance option for thermal energy storage (TES) systems used for nonresidential buildings. This application was submitted by Energysoft, LLC, of Novato, California.

The proposed compliance option would provide compliance credit under the *2005 Building Energy Efficiency Standards* (Standards) for nonresidential buildings when a TES system is installed.

TES systems reduce energy consumption during peak periods by shifting energy consumption to nighttime. Mechanical cooling system runs at night. Cooled fluid or ice is stored in a tank and is used for cooling during peak periods. The compressor operates at higher efficiency at lower ambient temperatures during the night. However, as charging of TES tank progresses, efficiency of the compressor decreases due to a lower temperature differential (lower heat transfer) at the chiller.

Staff supports approval of this compliance option on the condition that TES systems meet the acceptance testing and eligibility criteria specified in this report. Credit from approval of this compliance option would be applied to all TES systems that meet the acceptance requirements and eligibility criteria set forth in this compliance option. Compliance software could be updated to include this compliance option to model TES systems as specified in this report, and such software updates would need to be approved by the California Energy Commission.

SUMMARY OF APPLICANT'S REQUEST

The applicant proposed that compliance credit for TES systems be approved to reduce energy usage during hot, peak periods. Building energy use for the 2005 Standards is calculated using time dependent valuation (TDV) energy use, which places substantially higher value on saving energy during peak electricity periods. To calculate TDV energy use, hourly energy use is multiplied by a TDV multiplier. The TDV multiplier depends on the climate zone and on the hour of energy use.

The applicant presented proposed eligibility criteria and acceptance requirements in the application to qualify TES systems for compliance credit. The eligibility criteria address verification of specific measures that affect performance and reliability of the equipment. The acceptance requirements call for installer verification of control functions and the presence of required features. The eligibility criteria and acceptance requirements are discussed on page 5 of this report.

EVALUATION OF PROPOSAL

Staff evaluated the proposal using a research version of EnergyPro, an Energy Commission-certified compliance software program. Staff also evaluated the need for specific TES system features to ensure the reliability of the energy savings over the life of the equipment. The features are proposed as eligibility criteria.

Staff also evaluated the need for specific tests and checks to be made before building occupancy to ensure that the TES system performs efficiently and as designed. These tests and checks are proposed as acceptance testing. The installer is required to complete this acceptance testing and to provide a signed MECH-9-A form to the building department.

Compared to conventional cooling systems, TES systems require some additional routine simple maintenance checks (for example, periodic inspection and calibration of controls and visual inspection to check for leakages, overflow, and proper fluid level in the tank). This routine maintenance is expected to be conducted throughout the life of the equipment.

COMPLIANCE CREDIT ANALYSIS

Table 1 compares the standard energy budget of a minimally compliant building having a standard chiller for all the climate zones to a building with the same features and having a TES system.

TABLE 1

Energy saving based on a full load ice storage system

Climate Zone	Standard Design Total Energy KTDV/ sq ft-yr	Total Energy with TES KTDV/ sq ft-yr	Percent Savings	Standard Design Cooling Energy KTDV/ sq ft-yr	Cooling Energy with TES KTDV/ sq ft-yr	Percent Savings
1	159.3	154.8	2.8%	11.3	8.0	29.4%
2	173.6	164.3	5.3%	21.1	14.2	32.8%
3	167.9	160.2	4.6%	18.6	12.9	30.7%
4	178.3	165.0	7.5%	25.6	16.4	36.0%
5	170.0	163.6	3.8%	20.8	16.1	22.8%
6	196.5	187.2	4.8%	28.6	21.8	23.8%
7	183.4	172.4	6.0%	28.9	20.8	28.0%
8	203.8	190.5	6.5%	33.7	24.0	28.9%
9	203.9	190.2	6.7%	33.6	23.7	29.5%
10	204.3	190.4	6.8%	33.6	23.1	31.2%
11	181.9	170.4	6.3%	26.4	17.6	33.3%
12	180.2	168.2	6.6%	25.4	16.7	34.3%
13	187.0	172.4	7.8%	31.2	20.3	34.8%
14	205.8	192.0	6.7%	32.6	21.8	33.1%
15	225.5	203.6	9.7%	49.8	33.5	32.8%
16	174.4	167.1	4.2%	18.6	10.5	43.7%

A sample building with the following characteristics was used in the analysis:

- Building area: 315,000 sq. ft.
- Occupancy type: Medical office
- Five single duct VAV systems with heating provided by 30 percent VAV terminal boxes
- Lighting Power Density = 1.10 w/sq. ft.
- Window-to-Wall Ratio: 23%
- Two 300-ton centrifugal chillers using 0.576 kW/ton
- Two 300-ton cooling towers with two speed fans

For the building with the TES system, a 2,400- ton-hour Ice-On-Coil TES system was used. When ice produced by the TES system was being melted to meet the building cooling load, one chiller and one cooling tower were not operated in the simulation.

The reduction in energy shown in Table 1 represents the compliance credit resulting from installation of TES. The amount of compliance credit depends on the climate zone, cooling load and the capacity (ton-hour) of the TES system. Compliance credits for Climate Zone 4 and for Climate Zones 7 through 15 are substantial due to the large cooling loads in those climates.

Compliance credit for the TES system may be traded off by reducing the efficiency of other building features. Table 2 shows the impact of trading off the compliance credit in terms of increased lighting power density.

Table 2

Impact on lighting power density if compliance credit is completely traded off (relative to a Standard lighting requirement of 1.1 W/sq ft)

Climate Zone	Allowed Lighting Power (W/sq ft) with TES compliance credit	Increase in Lighting Power over Standard lighting requirement (W/sq ft)
1	1.20	0.10
2	1.28	0.18
3	1.26	0.16
4	1.35	0.25
5	1.22	0.12
6	1.25	0.15
7	1.30	0.20
8	1.30	0.20
9	1.33	0.23
10	1.35	0.25
11	1.33	0.23
12	1.33	0.23
13	1.38	0.28
14	1.33	0.23
15	1.44	0.34
16	1.30	0.20

Table 2 shows that the TES compliance credit allows the lighting power density to be increased from 0.1 to 0.34 w/sq ft depending on the climate zone, resulting in a percentage increase in lighting power of up to 30 percent.

Table 3 shows the impact to natural gas consumption when compliance credit is completely traded off by reducing building envelope energy efficiency features. The projected statewide increase in therms/yr is based on construction activity in 2003.

Table 3

Impact on natural gas use if compliance credit is completely traded off by reducing building envelope energy efficiency features

Climate Zone	Baseline Therms/yr	Therms/yr with TES if credit is completely traded off	Increase in Therms/yr
1	30,573	43,354	12,781
2	33,167	51,277	18,110
3	24,622	45,648	21,026
4	24,869	50,663	25,794
5	21,681	36,167	14,486
6	13,808	31,823	18,015
7	15,887	32,288	16,401
8	14,256	36,387	22,131
9	15,804	40,313	24,509
10	17,805	41,126	23,321
11	36,036	60,351	24,315
12	33,738	57,159	23,421
13	24,951	53,254	28,303
14	32,727	61,774	29,047
15	13,277	37,239	23,962
16	59,583	78,029	18,446

As shown in the Tables 2 and 3, compliance credit tradeoffs may result in increased electricity and natural gas use. Environmental impacts resulting from compliance credit tradeoffs are addressed on page 12 of this report.

ELIGIBILITY CRITERIA AND ACCEPTANCE TESTING

To ensure reliable energy savings and proper operation and control, the applicant worked with the staff to develop eligibility criteria and acceptance testing requirements.

Eligibility Criteria

The following types of TES systems are eligible for compliance credit:

- Chilled Water Storage
- Ice-on-Coil
- Ice Harvester
- Brine
- Ice-Slurry
- Eutectic Salt
- Clathrate Hydrate Slurry (CHS)

The following Certificate of Compliance information for both the chiller and the storage tank shall be provided on the plans, using the MEC-2-C (TES) form shown in Appendix A, to document the key TES System parameters and allow plan check comparison to the inputs used in the DOE-2 simulation. DOE-2 Keywords are shown in ALL CAPITALS in parentheses.

Chiller:

- Brand and Model
- Type (Centrifugal, Reciprocating, Other)
- Capacity (tons) (SIZE)
- Starting Efficiency (kW/ton) at beginning of ice production (COMP - KW/TON - START)
- Ending Efficiency (kW/ton) at end of ice production (COMP - KW/TON/END)
- Capacity Reduction (% / ^{o} F) (PER – COMP - REDUCT/F)

Storage Tank:

- Storage Type (TES-TYPE)
- Number of Tanks (SIZE)
- Storage Capacity per Tank (ton-hours) (SIZE)
- Storage Rate (tons) (COOL – STORE - RATE)
- Discharge Rate (tons) (COOL – SUPPLY - RATE)
- Auxiliary Power (watts) (PUMPS + AUX - KW)
- Tank Area (CTANK – LOSS - COEFF)
- Tank Insulation (R - Value) (CTANK – LOSS - COEFF)

Acceptance Testing

Acceptance testing also shall be conducted and documented on the MECH-9-A form shown in Appendix B. The form has two parts. In the TES System Design Verification part, the installing contractor shall certify the following information, which verifies proper installation of the TES System consistent with system design expectations:

- The TES system is one of the above eligible systems.
- Initial charge rate of the storage tanks (tons).
- Final charge rate of the storage tank (tons).
- Initial discharge rate of the storage tanks (tons).
- Final discharge rate of the storage tank (tons).
- Charge test time (hrs).
- Discharge test time (hrs).
- Tank storage capacity after charge (ton-hrs).
- Tank storage capacity after discharge (ton-hrs).
- Tank standby storage losses (UA).
- Initial chiller efficiency (kW/ton) during charging.
- Final chiller efficiency (kW/ton) during charging.

In the TES System Controls and Operation Verification part, the installing contractor also shall complete the following acceptance testing and certify to insure the TES System is controlled and operates consistent with the compliance simulation the results to the Building Department using form MECH-9-A (TES) shown in Appendix B.

1. Verify that the TES system and the chilled water plant is controlled and monitored by an energy management system (EMS).
2. Force the time to be between 9:00 p.m. and 9:00 a.m. and simulate a partial or no charge of the tank and simulate no cooling load by setting the indoor temperature set point higher than the ambient temperature. Verify that the TES system starts charging (storing energy).
3. Force the time to be between 6:00 p.m. and 9:00 p.m. and simulate a partial charge on the tank and simulate a cooling load by setting the indoor temperature set point lower than the ambient temperature. Verify that the TES system starts discharging.
4. Force the time to be between noon and 6:00 p.m. and simulate a cooling load by lowering the indoor air temperature set point below the ambient temperature. Verify that the tank starts discharging and the compressor is off.
5. Force the time to be between 9:00 a.m. to noon, and simulate a cooling load by lowering the indoor air temperature set point below the ambient temperature. Verify that the tank does not discharge and the cooling load is met by the compressor only.
6. Force the time to be between 9:00 p.m. and 9:00 a.m. and simulate a full tank charge by changing the sensor that indicates tank capacity to the Energy Management System so that indicates a full tank capacity. Verify that the tank charging is stopped.
7. Force the time to be between noon and 6:00 p.m. and simulate no cooling load by setting the indoor temperature set point above the ambient temperature. Verify that the tank does not discharge and the compressor is off.

ALTERNATIVE CALCULATION METHODS APPROVAL MANUAL SECTION

ACM Chapter 3 Optional Capabilities

This section provides recommended language for the Nonresidential ACM Manual, Section 3.3, HVAC Systems and Plant under the Subsection 3.3.16, Thermal Energy Storage (TES) Systems.

3.3.16 Thermal Energy Storage (TES) Systems

Since it is possible for the user to specify a TES system that has insufficient capacity to meet the load, the ACM shall ensure that the cooling load is met. This shall be accomplished by running additional chiller(s) to meet the load.

Description: The TDV energy savings associated with storing cooling energy during off-peak periods for use during high demand periods may be modeled by the ACM. The ACM shall simulate the TES system according to the following rules, criteria, inputs, and outputs:

1. The system includes a storage tank for storing cooling energy on-site.
2. The storage of cooling energy (charging) is accomplished though an active mechanism such as the pumping of chilled water and not a passive mechanism such as the storage of energy through the thermal mass of the building.
3. Charging is accomplished through an onsite chilled medium such as water or a eutectic solution but not by a direct expansion cooling system.
4. The system includes automatic controls that allow energy storage to occur during off-peak hours.
5. The system (TES-TYPE) is one of the following:

    - Chilled Water Storage
    - Ice-on-Coil
    - Ice Harvester
    - Brine
    - Ice-Slurry
    - Eutectic Salt
    - CHS

DOE Keyword: TES-TYPE
SIZE
COOL-STORE-RATE
COOL-SUPPLY-RATE
COOL-STORE-SCH
CTANK-BASE-T
CTANK-T-RANGE
CTANK-LOSS-COEF

COMP-KW/TON-START
COMP-KW/TON-END
EVAP-DELTA-T
REFRIG-T-AT-PC
PER-COMP-REDUCT/F
PUMP+AUX-KW

The evaporator delta T (EVAP-DELTA-T) shall specify the drop in refrigerant temperature as the system begins to charge. Values shall be set by the ACM as follows:

- Chilled Water - n/a
- Ice-on-Coil Systems – 4 º F
- Ice Harvester 4 º F
- Brine (Encapsulated Ice) – 4 º F
- Ice Slurry - 4 º F
- Eutectic Salt - 0 º F
- CHS - n/a

The refrigerant temperature (REFRIG-T-AT-PC) shall specify the refrigerant temperature at the start of the storage phase change. Values shall be set by the ACM as follows:

- Chilled Water - n/a
- Ice-on-Coil Systems - 22 º F
- Ice Harvester - 22 º F
- Brine (Encapsulated Ice) - 22 º F
- Ice Slurry - 22 º F
- Eutectic Salt - 41 º F
- CHS - n/a

For TES systems that use ice as a storage medium, additional parameters shall specify the efficiency of the chiller when it begins the charging process to make ice (COMP-KW/TON-START) and the efficiency of the chiller at the end of the charging process when ice making is complete (COMP-KW/TON-END). In addition, the reduction in chiller capacity that occurs as the temperature of the refrigerant is reduced during the ice making process (PER-COMP-REDUCT/F) shall be specified.

The thermal energy storage tank shall be simulated through the following additional ACM inputs:

- Storage capacity (SIZE) shall specify the total storage capacity of the system.
- Storage rate (COOL-STORE-RATE) shall specify the maximum rate at which the chiller can add cooling into the storage tank.

- Discharge rate (COOL-SUPPLY-RATE) shall specify the maximum rate at which cooling energy can be extracted from the storage tank.
- Base temperature (CTANK-BASE-T) shall specify the highest temperature of the storage medium delivered. This shall be fixed at 50 º F.
- Temperature range (CTANK-T-RANGE) shall specify the temperature difference between the Base temperature and the coldest storage temperature of the system. Values shall be set by the ACM as follows:

    - Chilled Water - 10 º F
    - Ice-on-Coil Systems - 18 º F
    - Ice Harvester - 18 º F
    - Brine (Encapsulated Ice) - 18 º F
    - Ice Slurry - 18 º F
    - Eutectic Salt - 6 º F
    - CHS - 6 º F

- Storage tank heat loss Coefficient (CTANK-LOSS-COEF) shall specify the product of the U-Value and area of the storage tank for determining the heat transfer loss between the storage tank and ambient conditions.

The ACM shall use a non-varying charging and discharging schedule for all TES systems (COOL-STORE-SCH). Charging will occur starting at 9:00 p.m. and ending at 9:00 a.m. Discharging will begin at noon and end at 6:00 p.m. The cooling load between 6:00 p.m. and 9:00 p.m. is met by the TES system (when the stored energy is available) or by the compressor (when the stored energy is not available). Between 9 a.m. and noon the tank does not discharge, and the cooling load is met by the compressor only.

Auxiliary energy use (PUMP+AUX-KW) shall specify any pumping or energy usage from devices such as air blowers used in the TES system.

Special requirements for ACM developers:

- The PERF-1, Special Features and Modeling section must have a note to alert the building department to inspect the TES system using the MECH-2-C (TES) form.

- The PERF-1 must alert the building department to the need for a Certificate of Acceptance for TES systems, MECH-9-A.

Input Type:	Required
Tradeoffs:	Yes
Modeling Rules for Proposed Design:	ACMs shall model features of TES systems as input by the user according to plans and specifications for the building.
Modeling Rules for Standard design:	ACMs shall model the system without TES systems according to the required systems and plant capabilities and Table N2-10.
Modeling Rules for Standard Design (Existing, Unchanged & Altered Existing):	ACMs shall model the existing system as it occurs in the existing standard design building. If the permit involves alterations, ACMs shall model the standard design as the existing, unchanged building with the systems that existed before alterations.

ACM Chapter 4 User's Manual and Help System Requirements

This section provides recommended language for inclusion in the nonresidential ACM manual, Section 4.4.3, HVAC systems and plant, related to the user documentation requirements. The language provided here is similar to that in the current ACM manual.

Thermal Energy Storage (TES) Systems

The ACM user's manual and help system shall describe the types of thermal energy storage (TES) systems that can be modeled. Describe all of the input parameters associated with the storage medium, and special inputs associated with the chiller operation, including when the system is charging the storage medium, meeting the cooling load with the compressor only, meeting the cooling load by discharging the storage medium only, and meeting the cooling load by either discharging the storage medium or with the compressor. Explain that this compliance option requires a special certificate of acceptance that must be filled out in the field, documenting acceptance testing of the TES system. Explain that this compliance option requires a special certificate of compliance to be included on the plans documenting specific TES system parameters.

ACM Chapter 5 Reference Method Comparison Tests

This section provides recommended language for inclusion in the nonresidential ACM manual, Section 5.3 optional capabilities tests.

5.3.9 O10 Test Series - Thermal Energy Storage (TES) Systems

This series tests thermal energy storage (TES) systems. This test uses the 10- zone version of building prototype B with the same features used (except as noted) in test C22C16.

Test O101C3: Building prototype C - Climate Zone 3 – San Francisco.

This test uses an ice-on-coil storage system to shift cooling load off-peak.

System parameters are identical to Prototype C, except as follows:

Chiller Type:	Water Cooled Centrifugal
Capacity:	25 tons
Efficiency:	0.6 kW/ton
TES Starting Efficiency:	0.7 kW/ton
TES Ending Efficiency:	0.8 kW/ton
Capacity Reduction:	2 %

Storage Tank Parameters:

Type:	Ice-on-coil
Storage Capacity:	150 ton-hrs
Storage Rate:	25 tons
Discharge Rate:	25 tons
Storage Tank Area:	220 sq. ft.
Storage Tank Insulation:	R-10

Test O102C12: Building prototype C - Climate Zone 12 – Roseville.

This test is the same system that was used for Test 0101C3. However, when used in Roseville, the TES system will have insufficient capacity. The ACM must assure that the additional load is met by backup chillers, or the system must fail.

Test O103C12: Building prototype C - Climate Zone 12 – Roseville.

This test uses a chilled water storage tank to shift cooling load off-peak.

System parameters are identical to Prototype C, except as follows:

Chiller Type:	Water Cooled Centrifugal
Capacity:	25 tons
Efficiency:	0.6 kW/ton

Storage Tank Parameters:

Type:	Chilled Water
Storage Capacity:	250 ton-hrs
Storage Rate:	40 tons
Discharge Rate:	40 tons
Storage Tank Area:	400 sq. ft.
Storage Tank Insulation:	R-20

Test O104C12: Building prototype C - Climate Zone 12 – Roseville.

This test uses an ice harvester storage system to shift cooling load off-peak.

System parameters are identical to Prototype C, except as follows:

Chiller Type:	Water Cooled Centrifugal
Capacity:	25 tons
Efficiency:	0.6 kW/ton
TES Starting Efficiency:	0.7 kW/ton
TES Ending Efficiency:	0.8 kW/ton
Capacity Reduction:	2 %

Storage Tank Parameters:

Type:	Ice-harvester
Storage Capacity:	250 ton-hrs
Storage Rate:	40 tons
Discharge Rate:	40 tons
Storage Tank Area:	250 sq. ft.
Storage Tank Insulation:	R- 20

Test O105C12: Building prototype C - Climate Zone 12 – Roseville.

This test uses a brine storage system to shift cooling load off-peak.

System parameters are identical to Prototype C, except as follows:

Chiller Type:	Water Cooled Centrifugal
Capacity:	25 tons
Efficiency:	0.6 kW/ton
TES Starting Efficiency:	0.7 kW/ton
TES Ending Efficiency:	0.8 kW/ton
Capacity Reduction:	2 %

Storage Tank Parameters:

Type:	Brine
Storage Capacity:	250 ton-hrs
Storage Rate:	40 tons
Discharge Rate:	40 tons

Storage Tank Area: 250 sq. ft.
Storage Tank Insulation: R-20

Test O106C12: Building prototype C - Climate Zone 12 – Roseville.

This test uses an ice-slurry storage system to shift cooling load off-peak.

System parameters are identical to Prototype C, except as follows:

Chiller Type: Water Cooled Centrifugal
Capacity: 25 tons
Efficiency: 0.6 kW/ton
TES Starting Efficiency: 0.7 kW/ton
TES Ending Efficiency: 0.8 kW/ton
Capacity Reduction: 2 %

Storage Tank Parameters:

Type: Ice-slurry
Storage Capacity: 250 ton-hrs
Storage Rate: 40 tons
Discharge Rate: 40 tons
Storage Tank Area: 250 sq. ft.
Storage Tank Insulation: R-20

Test O107C12: Building prototype C - Climate Zone 12 – Roseville.

This test uses a CHS storage system to shift cooling load off-peak.

System parameters are identical to Prototype C, except as follows:

Chiller Type: Water Cooled Centrifugal
Capacity: 25 tons
Efficiency: 0.6 kW/ton

Storage Tank Parameters:

Type: CHS
Storage Capacity: 250 ton-hrs
Storage Rate: 40 tons
Discharge Rate: 40 tons
Storage Tank Area: 250 sq. ft.
Storage Tank Insulation: R-20

Test Run Results:

The table below provides an example of the test run results that shall be reported for the ACM Tests.

Test	O101C3	O102C12	O103C12	O104C12	O105C12	O106C12	O107C12
Heating	27.12	31.23	31.23	31.23	31.23	31.23	31.23
Cooling	40.07	61.94	51.8	53.78	53.78	53.78	51.71
Lighting	54.78	54.86	54.86	54.86	54.86	54.86	54.86
Receptacles	34.44	34.53	34.53	34.53	34.53	34.53	34.53
Fans	70.59	78.57	78.57	78.57	78.57	78.57	78.57
Heat Rejection	16.29	22.49	18	18	18	18	18
Pumps/Misc	24.73	27.9	27.9	27.9	27.9	27.9	27.9
Process	0	0	0	0	0	0	0
DHW	40.17	40.17	40.17	40.17	40.17	40.17	40.17
Total	308.19	351.69	337.06	339.04	339.04	339.04	336.97

ENVIRONMENTAL IMPACT

Air Quality

Approval of this compliance option for TES systems will provide substantial cooling compliance credit. The credit may be traded off to allow other less efficient equipment and building envelope features. This may result in increased building space heating and/or cooling energy use. For example, this compliance credit may be traded off for measures such as more lighting power or reduced wall and ceiling insulation. Reduction in envelope efficiency features may increase space heating energy use, resulting in increased emissions of NO_x, CO, and PM_{10} at the building site.

It is hard to predict the expected market penetration of TES systems. To assess air quality impacts that could occur as a result of Energy Commission approval of the compliance option, staff evaluated a worst case scenario assuming 100 percent statewide market penetration. Minimally compliant buildings with standard design features in all the climate zones were used as the base case. For the proposed case, a TES system was added to the minimally compliant building, and the building lighting power density was increased until the building again became minimally compliant with the energy budget. In another scenario, the building envelope insulation was degraded until the building became minimally compliant. The onsite electricity and heating energy usage of the proposed building was compared to the base case. The increase in electric and natural gas energy usage were multiplied by emission factors that are applicable to power plant and natural gas furnaces, respectively, for each primary pollutant to estimate the potential worst case incremental emissions that could result from approval of the compliance option.[1]

[1] Note that reduced electricity consumption would reduce emissions at the power plant that generated the electricity (whether in California or at an out-of-state power plant that supplies electricity to California). These reduced emissions are not a negative environmental impact, and thus are outside this analysis. The location of the reduced emissions at the power plant is indeterminable.

Tables 4 and 5 show the estimated, worst-case, potential increase in emissions in comparison to total statewide emissions. The emission factors are based on California's statewide average furnace emissions factors developed by Energy Commission staff.

TABLE 4

Worst case increased emissions from approval of this compliance option when compliance credits are completely traded off by increased lighting power

	NO_x	CO	PM_{10}
Statewide worst case increased emissions from this compliance option (Tons/yr)	**4.09**	**2.48**	**.65**
Statewide total emissions (Tons/yr)	**1,244,449**	**6,376,204**	**1,174,229**
Worst case percent increase	**0.00032%**	**0.0000388%**	**0.0000553%**

TABLE 5

Worst case increased emissions from approval of this compliance option when compliance credits are completely traded off by reduced building insulation

	NO_x	CO	PM_{10}
Statewide worst case increased emissions from this compliance option (Tons/yr)	**56.03**	**16.81**	**5.6**
Statewide total emissions (Tons/yr)	**1,244,449**	**6,376,204**	**1,174,229**
Worst case percent increase	**0.0045%**	**0.000263%**	**0.000476%**

Table 6 shows the average emission factors for furnaces in California that were used in the analysis.

TABLE 6

Emission factors (Lbm per MMBtu)

Pollutants	NO_X	CO	PM_{10}
Emission factor	**0.05**	**0.03**	**0.01**

Table 7 shows the average emission factors for power plants in California that were used in the analysis.

TABLE 7

Emission factors (Lbm per kWh)

Pollutants	NO_X	CO	PM_{10}
Emission factor	**0.00038**	**0.00023**	**0.00006**

Staff finds no significant increase in emissions resulting from the approval of this compliance option.

STAFF CONCLUSIONS

Staff's preliminary analysis supports the approval of this compliance option. Staff believes that these types of TES systems will provide significant and reliable energy savings during peak periods. The reliability of savings will depend on compliance with eligibility criteria and acceptance testing requirements and on proper operation and maintenance practices.

Staff is requesting comments from the public and stakeholders related to the amount of compliance credit, environment impact, reliability of energy saving, eligibility criteria, acceptance requirements, compliance forms, ACM language, and other issues that the stakeholders may wish to resolve.

Please send your comments by January 16, 2007, to:

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If you have questions, contact Ram Verma at (916) 654-8435 or via e-mail at rverma@energy.state.ca.us

APPENDIX A

CERTIFICATE OF COMPLIANCE FORM

MECH-2-C (TES)

CERTIFICATE OF COMPLIANCE		MECH-2-C (TES)
Thermal Energy Storage (TES) Systems		
Project Name		Date

Component	**Parameter** (DOE-2 Keyword)	
Chiller	Brand and Model:	
	Type (Centrifugal, Reciprocating, etc):	
	Capacity (tons): (SIZE)	
	Starting Efficiency (kW/ton): (at beginning of ice production) (COMP-KW/TON-START)	
	Ending Efficiency (kW/ton): (at end of ice production) (COMP-KW/TON-END)	
	Capacity Reduction (% / F): (PER-COMP-REDUCT/F)	
Storage Tank	Storage Type (Check): (TES-TYPE)	☐ Chilled Water Storage ☐ Ice-on-Coil ☐ Ice Harvester ☐ Brine ☐ Ice-Slurry ☐ Eutectic Salt ☐ CHS
	Number of Tanks: (SIZE)	
	Storage Capacity per Tank (ton-hours): (SIZE)	
	Storage Rate (tons): (COOL-STORE-RATE)	
	Discharge Rate (tons): (COOL-SUPPLY-RATE)	
	Auxiliary Power (watts): (PUMP+AUX-KW)	
	Tank Area (sq ft): (CTANK-LOSS-COEFF)	
	Tank Insulation (R-Value): (CTANK-LOSS-COEFF)	

APPENDIX B

CERTIFICATE OF ACCEPTANCE FORM

MECH-9-A

2005 ACCEPTANCE REQUIREMENTS FOR CODE COMPLIANCE	MECH-9-A
Thermal Energy Storage (TES) System Acceptance Document	
Project Name	Date

TES System Design Verification		
1	TES system type	
2	Initial charge rate of the storage tanks (tons)	
3	Final charge rate of the storage tank (tons)	
4	Initial discharge rate of the storage tanks (tons)	
5	Final discharge rate of the storage tank (tons)	
6	Charge test time (hrs)	
7	Discharge test time (hrs)	
8	Tank storage capacity after charge (ton-hrs)	
9	Tank storage capacity after discharge (ton-hrs)	
10	Tank standby storage losses (UA)	
11	Initial chiller efficiency (KW/ton) during charging	
12	Final chiller efficiency (KW/ton) during charging	

TES System Controls and Operation Verification		
1	The TES system and the chilled water plant is controlled and monitored by an EMS.	☐ Pass ☐ Fail
2	Force the time to be between 9:00 p.m. and 9:00 a.m. and simulate a partial or no charge of the tank and simulate no cooling load by setting the indoor temperature set point higher than the ambient temperature. Verify that the TES system starts charging (storing energy).	☐ Pass ☐ Fail
3	Force the time to be between 6:00 p.m. and 9:00 p.m. and simulate a partial charge on the tank and simulate a cooling load by setting the indoor temperature set point lower than the ambient temperature. Verify that the TES system starts discharging.	☐ Pass ☐ Fail
4	Force the time to be between noon and 6:00 p.m. and simulate a cooling load by lowering the indoor air temperature set point below the ambient temperature. Verify that the tank starts discharging and the compressor is off.	☐ Pass ☐ Fail
5	Force the time to be between 9:00 a.m. to noon, and simulate a cooling load by lowering the indoor air temperature set point below the ambient temperature. Verify that the tank does not discharge and the cooling load is met by the compressor only.	☐ Pass ☐ Fail
6	Force the time to be between 9:00 p.m. and 9:00 a.m. and simulate a full tank charge by changing the output of the sensor to the EMS. Verify that the tank charging is stopped.	☐ Pass ☐ Fail
7	Force the time to be between noon and 6:00 p.m. and simulate no cooling load by setting the indoor temperature set point above the ambient temperature. Verify that the tank does not discharge and the compressor is off.	☐ Pass ☐ Fail

Certification Statement		
I certify that all statements are true on this MECH-9-A form, including the PASS/FAIL Evaluation. I affirm I am eligible to sign this form under the provisions described in the Statement of Acceptance on form MECH-1-A		
Name:		
Company:		
Signature:		Date: