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Summary Report of Persistence Studies: Assessments of Technical Degradation Factors, Final Report

Submitted to:
CADMAC Persistence Subcommittee
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SUMMARY OF PERSISTENCE STUDIES

1. Introduction

The Persistence Studies are part of a multi-faceted approach to estimating the persistence of energy savings from demand side management (DSM) programs in California. These studies were performed under contract to the California DSM Measurement Advisory Committee(CADMAC), Persistence Subcommittee. The Persistence Studies focused on one aspect of the persistence of savings — technical degradation. The results are tables of technical degradation factors (TDFs).

This summary report is designed to be suitable for utility consultants who may need to use the results of the Persistence Studies but do not need the background information, source documentation, or analysis and logic contained in the full reports. This document:

- defines the study measures in some detail,
- discusses the boundary between persistence and retention, and
- presents TDF summary tables that incorporate final results from all the Persistence Studies.

The TDFs published herein should be used for resource value calculations.

1.1. Project Research Objectives

The general research question is:

> *How will DSM program savings be affected over time by changes in the technical performance of efficient measures compared to the technical performance of the standard measures they replace?*

Other aspects of savings persistence such as measure life, measure retention, and market effects are being examined through a number of other studies and projects.

1.2. Technical Degradation Factors

The primary study result is a set of Technical Degradation Factors (TDFs). The TDFs are a series of yearly numbers which when multiplied by the first year savings yield an estimate of the energy savings in years subsequent to the first year. Specifically the TDF is defined as: "A scalar to account for time and use related change in the energy savings of a high efficiency measure or practice relative to a standard efficiency measure or practice." (CADMAC 12/17/97) The base level of performance is the period covered by the first year impact evaluation. The TDF is the ratio of savings in subsequent years to savings in the first year.

This calculation is independent of measure life as determined in the California evaluation protocols. The TDF is calculated for a 20 year period to allow for its independence from changes in the estimates of measure life.

1.3. Installation, Operation & Maintenance, and Retention Issues

Changes in energy usage that are due to operating conditions, product design, or human interaction are included within the scope of these studies. The performance of most efficient and baseline measures also depend upon installation, and operation & maintenance (O&M) practices. These factors were included within these studies to the extent that they were found to influence relative changes in measure performance over time.

The immediate impacts of any initial installation defects are assumed to be accounted for in first year impact studies. For example, if an energy management system is improperly installed, any reduction in its initial efficiency is not within the scope of this project; however, if installation defects lead to continuing declines in efficiency over time, then those effects are within the scope of these studies.

These studies do not cover "retention" issues. For instance, if a measure is removed before the end of its rated life, the decrease in energy savings is captured in the estimate of retention. The boundary between "retention" and "degradation" can potentially be drawn at different places. An example helps to clarify this. If a device is made inoperable, such as turning off an energy management system, that could be considered non-retention or technical degradation. The specific definition of "Technical Degradation Factor" was clarified by CADMAC on December 17, 1997. The clarification states if the device is physically present and operable, but not in use, it is considered to have experienced technical degradation (TDF = 0). If it is no longer physically present, or present but inoperable, it is considered non-retained.

2. Summary of Persistence Studies

There are five persistence studies. The short titles and abbreviations are: *Persistence 1* (P1), *Persistence 2* (P2), *Persistence 3A* (P3A), *Persistence 3B* (P3B), and *Neg-TDF Supplement* (PNg). Full references are given in Section 4.

2.1. Persistence 1 & 2

In *Persistence 1* and *Persistence 2*, an in-depth search of existing information was performed and the results were used to synthesize estimated TDFs. *Persistence 1* covered thirteen measures and *Persistence 2* covered twelve additional measures. The other persistence studies did not introduce any additional measures; they refined the TDFs for these measures. Table 3-1 displays the final TDFs.

2.2. Measure Definitions

The measure definitions from the original reports are listed below and summarized in Table 2-1. There are 25 measures, labeled M01-M25 in this report. (Report references are in parenthesis.)

M01: Residential air conditioners The baseline residential air conditioner was defined as a "builder's model" with a SEER of 10. The high efficiency units are defined as having a SEER of 11 or higher. (P1, PNg)

M02: Commercial air conditioners The commercial air conditioners are package units divided into three size categories corresponding to federal minimum efficiency classes. Baseline smaller capacity (<=5 tons) units have a SEER 10 rating, medium size units (6-12 tons) have an EER of 8.9, and larger units (13-20 tons) have an EER of 8.5. The efficient commercial units have efficiencies of at least SEER 11, EER 9.2, and EER 8.9 respectively. The studies focused on the most common baseline and high efficiency units. (P1, P3A)

M03: Oversized evaporative cooled condenser The baseline technology is a supermarket refrigeration system with an air cooled condenser. The efficient measure is the same system with an oversized evaporative cooled condenser. (P1)

M04: Residential refrigerators The baseline measure is a standard efficiency refrigerator which just meets the 1993 federal NAECA standard. The efficient measure is a refrigerator that exceeded the 1993 standard by greater than 15%. (P1, PNg)

M05: Electronic ballasts The baseline measure is an energy efficient magnetic ballast operating standard fluorescent T12 lamps. The efficient measure is an electronic ballast operating the same lamps. (P1)

M06: Electronic ballast and T8 lamp The baseline measure is a typical fluorescent fixture with T12 lamps and an energy efficient magnetic ballast. The efficient measure is T8 lamps with an electronic ballast. (P1)

M07: Optical reflectors The baseline was defined as a white enamel fixture with four lamps and a standard lens. The fixture may contain either 40 watt T12 or 32 watt T8 lamps with either an efficient magnetic ballast or an electronic ballast. The measure was defined as installing a front reflective silver film reflector, cleaning the lens, and delamping by removing two tubes and one ballast. (P1)

M08: High intensity discharge fixtures The baseline measure is defined as a 400-1000 watt mercury vapor fixture used indoors. The efficient measure is a 250 or 400 watt metal halide fixture in the same application. (P1)

M09: Occupancy sensors The baseline measure is a standard on/off switch. The efficient measure is an occupancy sensor, either ultrasonic or infra-red. (P1)

M10: High efficiency motors The baseline measures are either a new 10-20 hp motor or a rewound motor of 25-200 hp. The efficient measure is a new high efficiency motor of the same size. (P1)

M11: Adjustable speed drive for HVAC fan The baseline measure is a 100 hp motor operating a supply air fan controlled by variable inlet vanes or discharge dampers. The efficient measure is a pulse-width modulating (PWM) adjustable speed drive (ASD) controlling the same motor. (P1)

M12: Infrared gas fryer The baseline measure is a commercial gas-fired deep fat fryers equipped with standard atmospheric burners The efficient measure is a deep fat fryer equipped with an infrared burner. (P1)

M13: Residential ceiling insulation The baseline measure is defined as either R-11 insulation in an existing attic or code-required insulation in a newly built home's attic. The efficient measure is the addition of insulation to bring the existing home's R-value to 30 or the new home's R-value to 38. The most common insulation material is fiberglass, either batts or blown. (P1)

M14: LED exit signs The measure baseline is an Exit Sign with two 20 watt incandescent bulbs. The efficient measure is an LED Exit Sign with two 2 watt LEDs light sticks. (P2)

M15: Process adjustable speed drives — pumps The baseline measure is a pump in a waste water treatment facility for which variable flow rates are controlled by inlet throttling. The efficient measure is the same pump with an adjustable speed drive to vary flow rates. (P2)

M16: Process adjustable speed drives — injection molding The baseline measure is an injection molding machine with a continuous operation hydraulic pump with bypass control. The efficient measure is the injection molding machine retrofitted with an adjustable speed drive. The bypass remains in place, but bypassing is minimized by adjusting the ASD. (P2)

M17: Wall & floor insulation The baseline measures are R-13 fiberglass batt wall insulation and floor insulation in residential new construction. The efficient measures are R-15 fiberglass batt in the walls and R-19 in the floor. (P2)

M18: Daylighting controls — stepped The baseline technology is standard manually operated lighting. The efficient measure is stepped controls providing intermediate levels of electric light by progressively switching groups of lights off as daylight intensity increases. (P2)

M19: Daylighting controls — dimmable Dimmable daylighting controls adjust electric light output continuously to supplement available daylight. The controls are the most complex, and the system requires special lighting equipment capable of producing adjustable light output. The efficient measure is a standard office building retrofitted with photosensors controlling dimmable fluorescent lighting. (P2)

M20: Agricultural pumps The baseline measure is a standard vertical turbine agricultural pump that has worn and is operating at lowered efficiency. The efficient measure is an agricultural pump retrofitted with a new impeller and bowl assembly. Only the hydraulic efficiency of the pump bowl-impeller is considered. High efficiency electric motors are discussed elsewhere. (P2, PNg)

M21: Variable air volume HVAC systems The efficient measure is the installation of variable air volume HVAC distribution systems (VAV) in new commercial buildings. The baseline measure is installation of constant air volume HVAC distribution systems (CAV) in the same new commercial buildings. (P2)

M22: Energy management systems The energy efficient measure is installation of an energy management system (EMS) to control a commercial heating, ventilating, and air conditioning (HVAC) system. The baseline measure is standard control of HVAC system including manually set thermostats and on / off controls. (P2, P3A)

M23: Air compressors The baseline measure is an existing lubricant-flooded rotary screw air compressor. The efficient measure is a new lubricant-flooded rotary screw air compressor, with or without various efficiency enhancements. (P2, P3B)

M24: Compressed air distribution systems Header pressure in the baseline distribution system is supplied directly from the compressors. The piping system is marginally sized and leaky. Many regulators are set at maximum. Filters are clogged. Air is often used inappropriately. In the efficient system, the main header pressure is controlled by an expander from an adequately sized storage tank. The system is tight with few leaks and no large ones. The piping system is adequately sized to provide the rated flows. Regulators are set at the appropriate pressure to provide supply to the specific end-uses. Each end use is appropriate in function and quantity of air used. (P2, P3B)

M25: Compact fluorescent lamps The measure baseline is standard incandescent commercial lighting (one 100 watt incandescent A-lamp) in down-lighting and wall sconces. The efficient measure is a fixture with two hard-wired 13 watt CFL lamps on the same operating schedule. The fixture has an integral magnetic or electronic ballast with

replaceable 13 watt twin tube fluorescent lamps. Two 13 watt CFL provides the approximate lumen output of a standard 100 watt A-lamp. (P2)

Table 2-1 Study Measures

Measure #	High Efficiency Measure	Baseline Technology
M01	Residential Central A/C - high efficiency.	Standard SEER A/C
M02	Commercial A/C - Package DX	Standard efficiency unit
M03	Oversized evaporative cooled condenser	Air cooled condenser
M04	Refrigerator 10-30% better than std.	Standard efficiency refrigerator
M05	Electronic Ballast	Efficient magnetic ballast
M06	T8 with electronic ballast	T12 w/efficient magnetic ballast.
M07	Optical Reflector, delamp	Standard fixture
M08	HID interior Metal Halide 250-400W	Mercury vapor 400-1000W
M09	Occupancy Sensor	On/off switch
M10	Motor - high efficiency	Standard efficiency motors
M11	Adjustable Speed Drive for HVAC Fan	Variable inlet vanes or damper
M12	Infra-red Gas Fryer	Standard atmospheric fryer
M13	Residential ceiling insulation	Standard levels attic insulation
M14	LED exit signs	Incandescent exit signs
M15	Process adjustable speed drives — waste water pumps	Inlet vane throttling on waste water pumps
M16	Process adjustable speed drives — injection molding machines	Standard injection molding machines
M17	Fiberglass batt R-15 wall and R-19 floor insulation	R-13 fiberglass batt wall and floor insulation
M18	Switched or stepped daylighting controls	Standard manual lighting controls
M19	Dimmable daylighting controls	Standard manual lighting controls
M20	Agricultural pump repair or replacement	Existing agricultural pump
M21	Variable air volume HVAC distribution system	Constant air volume HVAC distribution system
M22	Energy management systems	Manual operation
M23	New air compressors	Existing air compressors
M24	High efficiency compressed air distribution system	Standard efficiency compressed air distribution system
M25	13 watt hard-wired compact fluorescent downlights	Incandescent downlights

2.3. Neg-TDF Supplement

In the original reports, *Persistence 1 & 2*, four measures were judged to experience negative degradation, i.e., were estimated to improve over time relative to the baseline:

- Residential DX ACs *Persistence 1*
- Residential Refrigerators *Persistence 1*
- ASD Process Pumping *Persistence 2*
- Agricultural Pumps *Persistence 2*

Originally the TDFs of these measures were set equal to one (1.00). In the *Neg-TDF Supplement* report, existing information was used to calculate negative TDFs (TDFs>1) for these four measures. These revised estimates are included in Table 3-1 below.

2.4. Persistence 3A & 3B

The second stage of the first two studies involved developing research plans for assessing technical degradation for those measures where substantial uncertainty was found in stage one. In *Persistence 1& 2*, further research plans were developed for two and five measures respectively, Table 2-2. CADMAC agreed to accept further TDF research of the three measures included in Persistence 3 studies in lieu of further study of the remaining four measures.

Table 2-2 Research Plans

***Persistence 1* Research Plans**	***Persistence 2* Research Plans**
Commercial Package Direct Expansion Air Conditioners Oversized Evaporative Cooled Condensers	ASD — Injection Molding Machines Daylighting Controls Variable Air Volume HVAC Systems **Energy Management Systems** **Compressors and Compressed Air Distribution Systems**

In *Persistence 3A*, new research was conducted and a new TDF based on this research was estimated for two of these measures: commercial package direct expansion air conditioners and energy management systems. The results of this research are included in Table 3-1.

The third measure, compressors and compressed air distribution systems is the focus of *Persistence 3B*. The study is incomplete, however, the TDF is fixed at 1.00 by the protocols. The TDFs used for resource value calculations will not be changed by the results of this study.

3. Summary Tables

Table 3-1 displays the TDFs estimated in *Persistence 1* & *Persistence 2* as modified by all subsequent reports. The displayed TDFs are the final TDFs to be used for resource value calculations under CADMAC protocols.

Table 3-1 Summary of TDFs

M#	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13
YEAR	Resid DX AC	Comm DX AC	Oversized Evap Condens	Resid Refrig	Electronc Ballasts	Elect Bal T8 lamps	Optical Reflectrs	HID fixtures	Occupancy Sensors	High Effic Motors	ASD HVAC Fan	Infrared Gas Fryer	Resid Ceiling Insulation
1*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	0.98	1.04	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
3	1.01	1.00	0.96	1.06	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
4	1.01	1.01	0.93	1.07	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
5	1.02	1.01	0.91	1.08	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
6	1.02	1.01	0.89	1.08	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
7	1.03	1.01	0.87	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
8	1.03	1.01	0.84	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
9	1.04	1.01	0.82	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
10	1.04	1.02	0.80	1.09	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
11	1.05	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
12	1.05	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
13	1.06	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
14	1.07	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
15	1.07	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
16	1.08	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
17	1.09	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
18	1.09	1.02	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
19	1.10	1.06	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
20	1.10	1.08	0.80	1.10	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00

* First year savings are one (1.00) by definition. The TDF modifies the first year savings for subsequent years.

Table 3-1 Summary of TDFs (continued)

M# / YEAR	M14 LED exit	M15 ASD Pump	M16 ASD IMM	M17 Wall&Flr Insul	M18 Stepped DLighting	M19 Dimmable DLighting	M20 Ag Pump	M21 VAV	M22 EMS	M23 Cmpr	M24 Cmpr Air Dist Sys	M25 CFL Downlite
1*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	0.98	1.00	1.00	0.73	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00	1.00	0.91	1.00	1.00	0.61	1.00	1.00	1.00	1.00	1.00	1.00
4	1.00	1.00	0.74	1.00	1.00	0.54	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	0.57	1.00	1.00	0.48	1.00	1.00	1.00	1.00	1.00	1.00
6	1.00	1.00	0.50	1.00	1.00	0.43	1.01	1.00	1.00	1.00	1.00	1.00
7	1.00	1.00	0.48	1.00	1.00	0.39	1.01	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	0.47	1.00	1.00	0.36	1.01	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	0.47	1.00	1.00	0.33	1.01	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	0.47	1.00	1.00	0.31	1.01	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	0.47	1.00	1.00	0.29	1.01	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	0.47	1.00	1.00	0.27	1.01	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	0.47	1.00	1.00	0.26	1.01	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	0.47	1.00	1.00	0.24	1.02	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	0.47	1.00	1.00	0.23	1.02	1.00	1.00	1.00	1.00	1.00
16	1.00	1.00	0.47	1.00	1.00	0.23	1.02	1.00	1.00	1.00	1.00	1.00
17	1.00	1.00	0.47	1.00	1.00	0.22	1.02	1.00	1.00	1.00	1.00	1.00
18	1.00	1.00	0.47	1.00	1.00	0.21	1.02	1.00	1.00	1.00	1.00	1.00
19	1.00	1.00	0.47	1.00	1.00	0.21	1.02	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	0.47	1.00	1.00	0.20	1.02	1.00	1.00	1.00	1.00	1.00

* First year savings are one (1.00) by definition. The TDF modifies the first year savings for subsequent years.

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