Technology Profile: Demand Control Kitchen Ventilation (DCKV)

Introduction and Emerging Technology Award Evaluation

Demand Control Kitchen Ventilation (DCKV)[1] is a method of modulating the speed (and therefore the energy consumption) of commercial kitchen ventilation (CKV). DCKV products compare favorably against the Emerging Technology Award criteria:

1. **Commercially available, but not widely adopted (<5% market share):**
   Yes, estimated at 0.5%--10% [1], though expected to increase to more than 10% due to new California Title 24 Building Energy Efficiency Regulations (effective January 1, 2014)
2. **Offered by more than one supplier:**
   Yes, at least 11 suppliers;
3. **Demonstrated in environmental performance; third party verified:**
   Yes, performance verified through case studies conducted by utilities, though comprehensive data are in the process of being assembled;
4. **Likely to significantly reduce greenhouse gases at competitive costs**
   Yes, offers high percentage savings for the kitchen's biggest load;
5. **Environmentally acceptable (technology use is a net plus for the environment):**
   Yes, composed of standard electronic components, similar to computers;
6. **Supported by capable partners who are adequately financed with established business records:**
   Yes, multiple established and well-respected companies that have been in the commercial kitchen ventilation business of several years;
7. **Well matched to EPA/ENERGY STAR competencies and appropriate roles:**
   Yes, commercial kitchen ventilation is the single biggest user of energy in a commercial food service facility [1], and addressing it through DCKV would build on previous ENERGY STAR success with commercial food service (CFS) specifications. EPA has a vast network of key stakeholders needed to promote the Award, including dealer networks, restaurants, utilities, hospitality, and large buying groups.

Technology Description

Commercial kitchen ventilation removes the heat and effluent generated by the cooking process from the kitchen space, ensuring the comfort and safety of the cooking staff and preventing cooking odors from spreading beyond the kitchen. Commercial kitchen ventilation is composed of an average of two hoods suspended above the cooking appliances, and ducting and fans necessary to expel the heat and effluent outside [2]. To replace the air lost through this process, make-up air (MUA) must be provided by the building's heating ventilation and air-conditioning (HVAC) system or a MUA system dedicated to the kitchen, which is composed of its own fans, ducts, and potentially heating or cooling, depending on the climate.

DCKV provides control over the ventilation system by modulating the speed depending on cooking activity. Traditionally commercial kitchen ventilation systems would operate at their maximum designed speed/volume throughout the duration of a kitchen's operating hours or provide manual control over two speeds [3]. DCKV, in contrast, provides automatic, continuous control over fan speed in response to

[1] Demand control ventilation (DCV) has broader application beyond commercial kitchens (e.g., venting in multi-family buildings), therefore DCKV is used to describe commercial kitchen systems throughout this report.

temperature, optical, or infrared (IR) sensors that monitor cooking activity or direct communication with cooking appliances. [4]

Technical Potential
DCKV provides the following benefits over traditional commercial kitchen ventilation:

Energy consumption reduction due to decreased fan speeds.
DCKV systems save energy compared to non-DCKV systems as cooking equipment is not used all at once nor all the time. Thus the amount of savings due to the reduction in fan speed is dependent on two factors:

1. Number of appliances used at once: commercial kitchen ventilation systems are designed for the maximum load of the appliances under each hood for safety and comfort. Since all appliances are unlikely to operate at once, the ventilation system is operating at higher capacity than necessary. The energy savings due to this factor will depend on the combination of appliances under the particular hood controlled by DCKV and the way they are used.
2. Time that appliances are used: even if all the appliances under a particular hood *are* used at once, they will not be used the entire time the kitchen is operating. The energy savings due to this factor will depend on the kitchen's operating schedule.

Figure 1, below, illustrates these two factors. Please note that these two factors, and therefore the majority of the energy savings, are installation dependent.

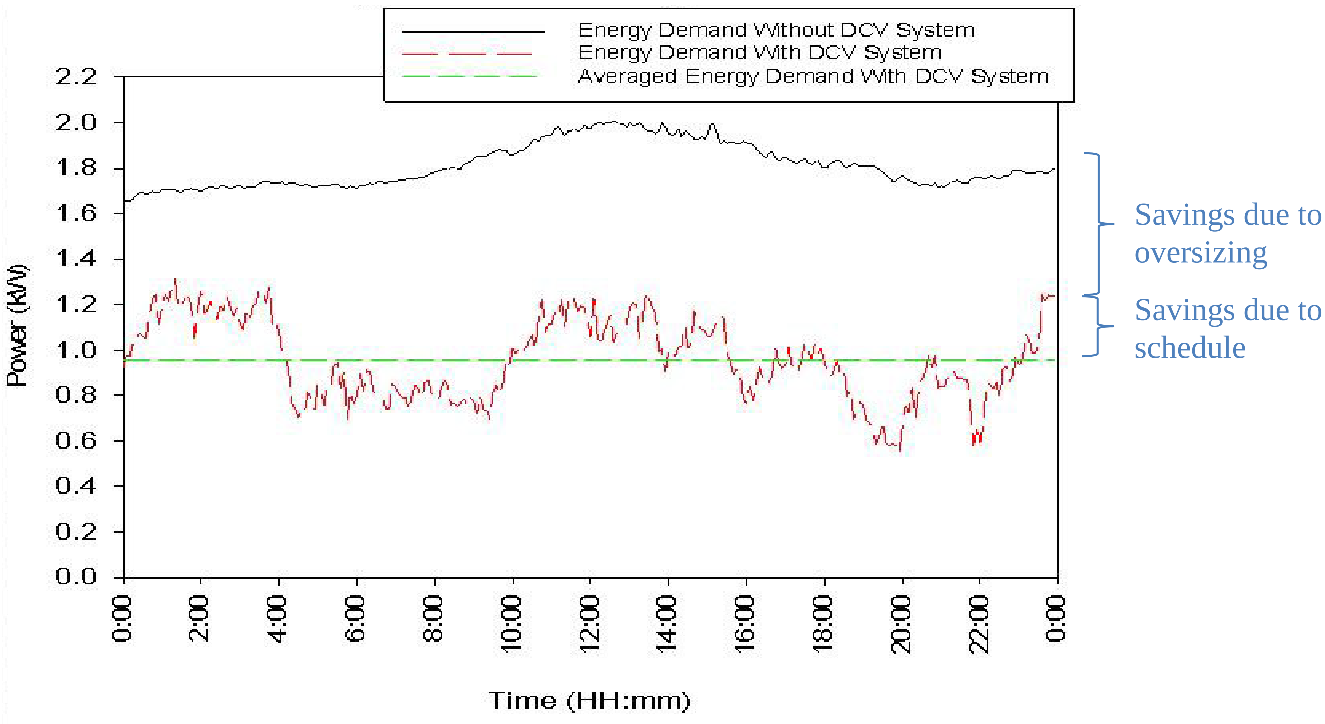

Figure 1: Typical power demand and savings from one exhaust fan due to a DCKV retrofit in a hotel kitchen [5].

Figure 1 shows a reduction in average power (and therefore energy savings) of 57%. Due to the large size of the (hotel) kitchen where the system was installed (there were several similar exhaust systems), this translated to 60,439 kWh/year or $9,066 using local electricity rates [5] ($5,814 using the 2013 U.S. average commercial rate). The percentage savings are typical of kitchens where all the appliances are not typically used (oversizing) and that have appliances with heat loads that increase when cooking (scheduling), for example:

- Multiple cooklines, only some of which are typically used;
- Appliances that heat up quickly and produce a heat load only when being actively used (e.g., woks, light-duty and medium-duty appliances),
- Appliances that produce a low heat load, but that produce changing amount of effluent when cooking (e.g., fryers)

In contrast, where appliances produce a constant heat load and are used all the time, the savings are lower. An example of a kitchen with lower savings is one with charbroilers that are on constant heat throughout the day, and the savings can only be achieved during warm-up and cool-down. The savings achieved in this case was 37%. [5]

An additional factor, not specifically noted in Figure 1, is the minimum energy consumption of the system. This is the lowest point of the brown dashed line Figure 1 and occurs when all appliances are idle. This, together with the other two factors will impact the average power and energy consumption of the final DCKV system, and is itself impacted by:

- The minimum fan speed for safe operation: Fan speeds below 500 fpm (3 m/s) could lead to deposition of grease in the duct and fire danger; [4]
- The responsiveness of the system: Systems that respond more slowly to cooking activity may delay exhausting cooking effluent and heat; therefore, to prevent this initial accumulation of effluent and user dissatisfaction, their minimum fan speed may be increased relative to more responsive systems, decreasing savings during idle periods and therefore average savings. [6]

This last factor is worth highlighting as it is the only one that is controlled by the manufacturer and is not installation-dependent. Manufacturers can increase the responsiveness of their systems through one of four methods:

- Placing the thermometer(s) closer to the cooking appliance;
- Providing an optical sensor to detect effluent;
- Using an infrared sensor to detect temperature changes remotely rather than waiting for the heat or effluent to waft up ; and
- Directly communicating with the cooking appliances [4].

In the past two years, the number of DCKV systems with multiple thermometers (for placement closer to the cooking appliances) and remote sensors has increased. [7] This has led to further energy savings in some installations where the cooking load is highly variable and the fan speed was decreased significantly during idle periods. [4] A diagram of a system using infrared sensors is shown in Figure 2, below.

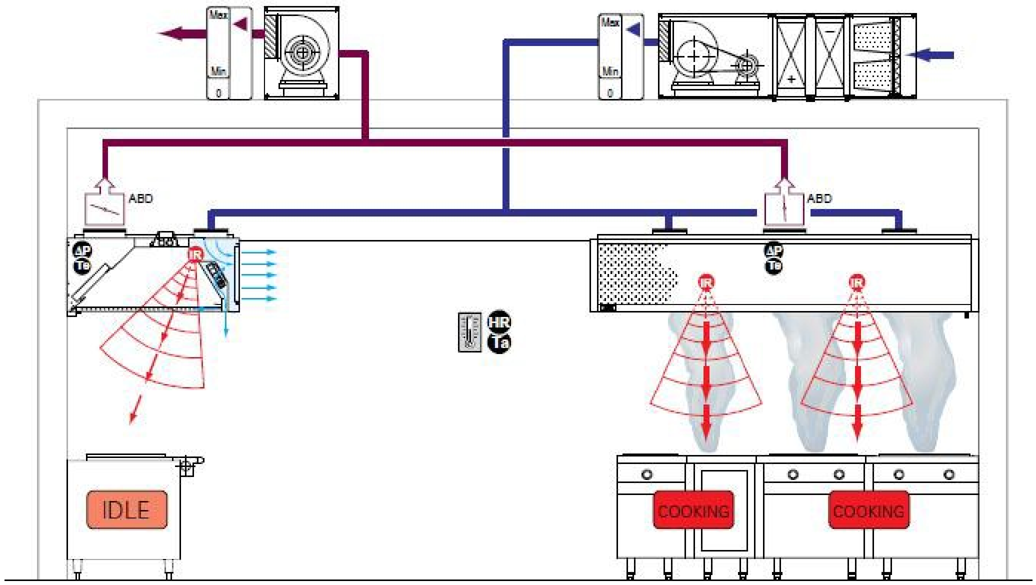

Figure 2: Diagram of a DCKV system with infrared sensors that remotely monitor the cooking surfaces [8].

Energy consumption reduction due to decreased MUA

An additional source of savings, especially in cold or hot climates, is the reduction in the volume of make-up air (MUA) that must be conditioned (heated or cooled) prior to returning to the kitchen to replace the air lost through the ventilation system. This is significant enough that one of the largest promoters of DCKV is a Canadian gas utility. [7] In one case study of a hotel kitchen in San Francisco, CA, the 30% reduction in MUA that had to be heated accounted for 48% of the cost savings from the DCKV retrofit. [9]

Continuous Monitoring

One additional benefit of some DCKV systems is that their controllers are network-connected, allowing outside parties to monitor the system's operation. This ensures correct installation, and can help prevent degradation of performance over time. [7]

Existing Market Share

The market share of DCKV for new systems was estimated at between 0.5% and 10% in 2010 or between 500 and 10,000 units. Furthermore, up to 1% of installed commercial kitchen ventilation systems are estimated be retrofitted with DCKV each year, leading to additional U.S. shipments of no more than 10,000. One manufacturer estimates the retrofit market at 700 units per year. [1]

One factor that may increase the awareness and spread of DCKV is that the 2013 California Title 24 building efficiency regulations (effective January 1, 2014) now require commercial kitchens greater than 5,000 cfm to decrease the amount of conditional MUA they require, and DCKV is one option to meet the requirement (see Appendix 2) . For example, a Panda Express restaurant analyzed in [5] had a total exhaust capacity of 6,000 cfm, while a Westin hotel kitchen had a total capacity of 21,594 cfm. Most new and renovated kitchens in California will therefore be subject to the requirements and may elect DCKV, raising the market share past 10% (Californians make up 12% of the U.S. population).

Barriers to Market Adoption

Despite two decades in the market [4], and 30 utility programs now offering rebates for installation [7], awareness and market share of DCKV remain low. There are several barriers to wider market adoption:

Education

Several sources noted that education of installers and end-users is a barrier. While larger institutions and their food-service equipment consultants are aware of DCKV and are employing the technology, it has yet to reach other market segments:

- Chain restaurants are aware of the technology, but have not yet seen a business case for employing it. Widespread adoption could take 5 years.
- Independent restaurants are not aware of the technology and neither are their dealers. Widespread adoption could take 10–20 years. [7]

Also, installing DCKV requires mechanical and electrical contractors to integrate several different systems: the ventilation system, variable speed drives and controls, the building's HVAC system. Doing so competently to ensure performance across the full range of speeds is difficult, so there is opportunity to simplify installation [4].

Lastly, although DCKV has been promoted through organizations such as ASTM International and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) [6], a wider spotlight via organizations that engage commercial kitchen operators and designers directly, such as the National Restaurant Association (NRA) and the Foodservice Consultants Society International (FSCI), could be beneficial.

Differing/Uncertain Criteria

As mentioned above, there are currently 30 utility programs that promote DCKV systems [10]; however, the total number of systems incented to date in the United States and Canada is low. One factor contributing to this lack of uptake may be the differing criteria that utility programs use to determine which DCKV systems can receive incentives, which could make it difficult to market DCKV across utility territories. See Table 1, below, for a summary of the differing program requirements.

Table 1: Number of utility programs that have criteria requiring specific components [10].

Component Requirements	# of Programs*
Sensor Requirements	7
Motor Requirements	7
MUA Requirements	5
Pre-approved Systems Only	7
Unclear or unspecified	9

* Note: list is not mutually exclusive, with several programs requiring multiple components.

Variability in Savings

Due to the variations in kitchen design and operation and local climate, the savings due to DCKV will vary for each installation. One source describes the savings as:

> a function of the actual exhaust ventilation rate, geographic location, operating hours of the system, static pressure and fan efficiencies, makeup air heating setpoint, makeup air cooling setpoint and level of dehumidification, efficiency of heating and cooling systems, level of interaction with kitchen HVAC system, appliances under the hood and associated heat gain to space, and applied utility rates. [4]

This variability in installed savings and lack of a standardized test procedure (described below) may make purchasers hesitant; however, the Consortium for Energy Efficiency (CEE) is in the process of compiling DCKV test data in a variety of settings, including data by different manufacturers in similar facilities, the same manufacturer in similar facilities, and the same manufacturer in different facilities. These case studies could be used to more confidently estimate potential savings.

Long Payback Period

Despite the high percentage savings of DCKV, and the high energy consumption of commercial kitchen ventilation relative to other appliances in the kitchen, some purchasers could experience long payback periods, as illustrated in Table 2. Based on data collected in 2009, DCKV retrofits seem to suffer from high fixed costs (likely due to the cost of the controller, user interface, and installation complexity), and variable savings, such that the largest facilities will experience the shortest paybacks. Whether the install cost has decreased since 2009 would need to be investigated further, however, the cost of new installations is expected to be lower. [1]

Table 2: Percentage and annual cost savings due to DCKV retrofits compared to install cost [5].

Facility Type	DCKV Percentage Energy Savings	DCKV Annual Cost Savings	DCKV Retrofit Install Cost	DCKV Payback Period (yr)
Hotel	61.7%	$22,623	$28,000	1.2
Hotel	57.0%	$9,066	$22,000	2.4
Quick service rest.	37.5%	$1,481	$15,500	10.5
Quick service rest	61.2%	$2,259	$8,000	3.5
Quick service rest	48.8%	$1,183	$9,000	7.6

Status of Test Procedures

ASTM International Committee F26 is actively developing a laboratory test method for DCKV. Performance will be measured with two different appliance lines to simulate two representative equipment set-ups found in the field:

1. Medium-duty line: 2 vat fryer / griddle / oven
2. Heavy-duty line: 2 vat fryer / under-fired broiler (no lid) / convection oven

The test method should be finalized by early 2015. [11]

ASTM F1704-12, Standard Test Method for Capture and Containment Performance of Commercial Kitchen Exhaust Ventilation Systems, does specify idle and cooking conditions for test, and may provide a path forward toward developing a laboratory test method for DCKV. [6]

In the meantime, manufacturers and utilities are using ASTM F2976-13, Standard Practice for Determining the Field Performance of Commercial Kitchen Demand Control Ventilation Systems [12]. This is a field-test protocol originally developed by the Consortium for Energy Efficiency (CEE), which can be used for evaluating new-construction and retrofit systems. Under this protocol, a baseline is first established as follows:

- New-install systems: The DCKV system is put into a manual override, such that it operates as its maximum design speed, and a one-time power measurement is conducted;
- Retrofit systems: Prior to the installation of the DCKV system, the performance (in kW and kWh) of the existing non-DCKV system is monitored for two weeks or more.

This baseline can then be compared to the performance (in kW and kWh) of the new-install or retrofit DCKV systems, which is monitored for two weeks or more.

Appendix 1: References

Bibliography

[1] Consortium for Energy Efficiency, "Commercial Kitchen Ventilation: An Energy Efficiency Program Administrator's Guide to Demand Control Ventilation," Boston, 2010.

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[3] J. Hermias, Interviewee, *Chef, Thally Restaurant, Washington, DC.* [Interview]. 29 September 2013.

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[5] Southern California Edison, "Demand Control Ventilation for Commercial Kitchen Hoods," 2009.

[6] R. Swierczyna, Interviewee, *CKV Lab Manager, Fisher-Nickel, inc.*. [Interview]. 29 October 2013.

[7] K. Erickson, Interviewee, *Program Manager, Commercial Kitchens Committee, Consortium for Energy Efficiency*. [Interview]. 25 October 2013.

[8] Halton, "13 Coins Case Study: Airflow and Energy Savings with the Halton MARVEL System," Halton, 2013.

[9] Food Service Technology Center, "Demand Ventilation in Commercial Kitchens: An Emerging Technology Case Study," Pacific Gas and Electric Company, San Francisco, CA, 2004.

[10] Consortium for Energy Efficiency, "CEE 2013 Commercial Kitchens Program Summary," 21 June 2013. [Online]. Available: http://library.cee1.org/content/cee-2013-commercial-kitchens-program-summary/. [Accessed 23 October 2013].

[11] ASTM International F26.07 Task Group on Demand Control Kitchen Ventilation, *Update to the F26 Committee*, Chicago, May 20, 2014.

[12] Consortium for Energy Efficiency, "Commercial Kitchen Ventilation Demand Control Ventilation Field Test Protocol Version 1.0," 23 January 2012. [Online]. Available: http://library.cee1.org/content/cee-ckv-dcv-field-test-protocol-version-10/.

Appendix 2: DCKV Excerpt of 2013 California Title 24 Building Energy Efficiency Regulations

SECTION 140.9 – PRESCRIPTIVE REQUIREMENTS FOR COVERED PROCESSES

(a) **Prescriptive Requirements for Computer Rooms**

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(b) **Prescriptive Requirements for Commercial Kitchens.**

1. **Kitchen exhaust systems.**

A. Replacement air introduced directly into the hood cavity of kitchen exhaust hoods shall not exceed 10percent of the hood exhaust airflow rate.

B. For kitchen/dining facilities having total Type I and Type II kitchen hood exhaust airflow rates greater than 5,000 cfm, each Type I hood shall have an exhaust rate that complies with TABLE 140.9-A. If a single hood or hood section is installed over appliances with different duty ratings, then the maximum allowable flow rate for the hood or hood section shall not exceed the TABLE 140.9-A values for the highest appliance duty rating under the hood or hood section. Refer to ASHRAE Standard 154-2011 for definitions of hood type, appliance duty and next exhaust flow rate.

EXCEPTION 1 to Section 140.9(b)1B: 75 percent of the total Type I and Type II exhaust replacement air is transfer air that would otherwise be exhausted.

EXCEPTION 2 to Section 140.9(b)1B: Existing hoods not being replaced as part of an addition or alteration.

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted Canopy	140	210	280	385
Single Island	280	350	420	490
Double Island	175	210	280	385
Eyebrow	175	175	Not Allowed	Not Allowed
Backshelf / Passover	210	210	280	Not Allowed

TABLE 140.9-A MAXIMUM NET EXHAUST FLOW RATE, CFM PER LINEAR FOOT OF HOOD LENGTH

2. **Kitchen ventilation.**

A. Mechanically cooled or heated makeup air delivered to any space with a kitchen hood shall not exceed the greater of:

i. The supply flow required to meet the space heating and cooling load; or

ii. The hood exhaust flow minus the available transfer air from adjacent spaces. Available transfer air is that portion of outdoor ventilation air serving adjacent spaces not required to satisfy other exhaust needs, such as restrooms, not required to maintain pressurization of adjacent spaces, and that would otherwise be relieved from the building.

EXCEPTION to Section 140.9(b)2A: Existing kitchen makeup air units not being replaced as part of an addition or alteration.

B. A kitchen/dining facility having a total Type I and Type II kitchen hood exhaust airflow rate greater than 5,000 cfm shall have one of the following:

i. At least 50 percent of all replacement air is transfer air that would otherwise be exhausted; or

ii. Demand ventilation system(s) on at least 75 percent of the exhaust air. Such systems shall:

a. Include controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle; and

b. Include failsafe controls that result in full flow upon cooking sensor failure; and

c. Include an adjustable timed override to allow occupants the ability to temporarily override the system to full flow; and

d. Be capable of reducing exhaust and replacement air system airflow rates to the larger of:
(c) 50 percent of the total design exhaust and replacement air system airflow rates; or
(d) The ventilation rate required per Section 120.1.

iii. Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40 percent on at least 50 percent of the total exhaust airflow; and

iv. A minimum of 75 percent of makeup air volume that is:

a. Unheated or heated to no more than 60°F; and

b. Uncooled or cooled without the use of mechanical cooling.

EXCEPTION to Section 140.9(b)2B: Existing hoods not being replaced as part of an addition or alteration.

3. **Kitchen Exhaust System Acceptance.** Before an occupancy permit is granted for a commercial kitchen subject to Section 140.9(b), the following equipment and systems shall be certified as meeting the Acceptance Requirements for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements specified in NA7.11.

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