**Work Paper PGECOHVC144**

**Cogged V-Belts**

**Revision # 1**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**HVAC Fans Cogged V-belt Replacement**

**Measure Codes SA13, SA14, SA15**

**PGECOHVC144**

**Cogged V-Belts**

PG&E is using the SCE workpaper **SCE15HC040 Revision 1** ex-ante values for PG&E measure codes SA13, SA14 and SA15.

# Work Paper Approvals

The following Manager(s) approved this workpaper through the PG&E Electronic Data Routing System under Routing Requisition # \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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| --- |
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**Work Paper SCE15HC040**

**Revision 1**

**Southern California Edison Company**

**Cogged V-Belt Non-Residential HVAC Fans**

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | SA13, SA14, SA15 |
| **Measure Description:** | The replacement of smooth V-belts in non-residential package rooftop HVAC systems with cogged V-belts |
| **Base Case Description:** | Typical existing smooth fan belts |
| **Energy Impact Common Units:** | kW/ton, kWh/ton |
| **Energy Savings :** | Refer to Excel Calculation Attachment |
| **Gross Measure Cost ($/unit)** | This work paper does not report base case and measure costs as those costs are between the program and their contractors for direct install programs. |
| **Measure Incremental Cost ($/unit):** | This work paper does not report base case and measure costs as those costs are between the program and their contractors for direct install programs. |
| **Effective Useful Life (years):** | 2.7 to 5 years, depending on building type |
| **Measure Application Type:** | Replace on Burnout (ROB) |
| **Net-to-Gross Ratios:** | 0.85 |
| **Important Comments:** | |

# Document Revision History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Workpaper and Revision # | Tech. Revision | MM/DD/YY | Author/Affiliation | Summary of Changes |
| SCE13HC040, Revision 0 | No | 4/19/2012 | Janice Peterson, PECI | Original work paper for 2013 PC |
| SCE15HC040, Revision 1 | No | 4/14/2014 | Matt Tyler, PECI | Updated energy and demand savings using updated weather files, included all 16 climate zones |

# Section 1. General Measure & Baseline Data

This work paper details the replacement of smooth v-belts in non-residential unitary (packaged) rooftop HVAC systems with cogged v-belts as shown in Table 1. A v-belt typically connects the motor and the supply air fan. Some of the larger unitary equipment may also have a v-belt between the return air motor and fan. The base case is a rooftop unit (RTU) that contains one or more smooth v-belts. The measure replaces them with new cogged (notched) v-belts. The savings are calculated for 19 building types and three system types in all California climate zones. The three system types are gas packs, unitary AC-only, and heat pumps.

## 1.1 Measure Description & Background

**Measure Description:** The replacement of smooth v-belts in non-residential package rooftop HVAC systems with cogged v-belts

**Basecase Description:** Typical existing smooth fan belts

Table 1 Measure Names

|  |  |
| --- | --- |
| Solution Code | Measure name |
| SA13 | HVAC Fans Cogged V-belt Replacement for Gas Packs |
| SA14 | HVAC Fans Cogged V-belt Replacement for Heat Pumps |
| SA15 | HVAC Fans Cogged V-belt Replacement for Unitary AC-Only |

**Eligibility Requirements:** The participant must have electricity distributed by SCE or PG&E to the installation service address. This measure does not apply if the RTU already has cogged V-belts.

**Implementation Requirements:** This measure can be applied to supply air and return air fans in RTUs that do not already have a cogged V-belt installed.

**Documentation Requirements:** Necessary for the measures to be eligible for savings, i.e. invoice records for actual base cases versus DEER assumptions. The documentation requirements may be related at the measure level or the delivery mechanism level.

## 1.2 Technical Description

This work paper details the replacement of smooth v-belts in non-residential package and split HVAC systems with cogged v-belts. A v-belt typically connects the motor and the supply air fan. Some of the larger unitary equipment may also have a v-belt between the return air motor and fan. The base case assumes an RTU contains one or more smooth v-belts and the measure requires replacing them with new cogged (notched) v-belts and new pulleys if required. This measure does not apply if the RTU already has cogged v-belts.

The typical smooth v-belts are usually referred to in five basic groups:

* “L” belts are low end belts that are for small, fractional horsepower motors and these are not used in RTUs.
* “A” and “B” belts are the two types typically used in RTUs. The “A” belt is ½ inch width by 5/16 inch thickness. The “B” belt is larger, 21/32 inch wide and 12/32 inch thick so it can carry more power. V-belts come in a wide variety of lengths where 20 to 100 inches is typical.
* “C” and “D” belts are primarily for industrial applications with high power transmission requirements.

V-belts are available from various vendors. The cogged version of these belts typically have an “X” added to the designation or model number. For this HVAC Fans Cogged V-Belt Replacement measure, only the “A” and “B” v-belts are considered. A typical “A” v-belt is replaced by a cogged “AX” v-belt and a “B” is replaced by a “BX.” In general, smooth v-belts have an efficiency of 90% to 98% while cogged v-belts have an efficiency of 95% to 98%. Because cogged v-belts are more flexible they are compatible with smaller diameter pulleys and they have less resistance to bending. Lower bending resistance increases the power transmission efficiency, lowers the waste heat, and allows the belt to last longer than a smooth belt.

In particular, four research papers [A][B][C][D] show that the cogged v-belt efficiency is 0.4% to 4.8% better than a typical smooth v-belt. A fifth paper by USDOE’s Energy Efficiency and Renewable Energy [E] group reviewed most of the earlier literature and recommended using a conservative 2% efficiency improvement for energy savings for calculations.

A review of the online Grainger [F] pricing for “A,” “B,” “AX” and “BX” v-belts showed the incremental cost to be about 20% more per belt in sizes typical for RTUs.

## 1.3 Measure Application Type

Note: See Appendix A for a comparison of the application types used by and incorporated into SCE systems versus the application types available in the newest revision of DEER 2014. Appendix A will serve as a translation between the outputs of this workpaper and application types used by READi.

**SCE Delivery Mechanism:** Financial Support – Direct Install

**SCE Program type:** RET

**PG&E Delivery Mechanism:** Financial Support – Direct Install

**PG&E Program type:** ROB

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

This section of the work paper explains the reasoning behind using a calculation method that deviates from the DEER database.

This measure is not addressed in any version of the Database for Energy Efficient Resources (DEER05, DEER08, DEER11, or DEER14)[[1]](#footnote-1). This measure does use DEER2014 prototypes generated using MASControl v3.00.19. The prototypes were generated using the Customer Average (CAv) case option for the following tech IDs:

* D08-NE-HVAC-airAC-SpltPkg-110to134kBtuh-11p0eer
* D08-NE-HVAC-airHP-SpltPkg-110to134kBtuh-11p5eer-3p4cop

Table 2 DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Difference Summary Table** | |
| Modified DEER Methodology | No |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | Yes |
| Deviation from DEER | N/A |
| DEER Version | N/A |
| DEER Run ID and Measure Name | N/A |

**Net to Gross**

The NTG value was obtained from the “DEER2011\_NTGR\_2012-05-16.xls” on the DEER website as required by Version 5 of the California Public Utilities Commission (CPUC) Energy Efficiency Policy Manual [351]. The relevant NTGR for this measure is shown in Table 3 below.

Table 3 Net-to-Gross Ratio

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | NTG\* |
| Com-Default-HTR-di | All other EEM with no evaluated NTGR; direct install to hard-to-reach only. | Com | Any | DirInstall | 0.85 |

\*Denotes that the column is taken from the DEER NTG Table.

**Installation Rate**

The installation rate (IR) is identified in the calculation attachment. This value is obtained from the support table available in READi. Currently there is no versioning on the installation rate table. To address appropriate selection of the installation rate the date of the workpaper will serve as the last date checked for updated IR values. The installation rate varies by end use, sector, technology, application, and delivery method. The relevant IR values for this measure are shown in Table 4 below.

Table 4 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| GSIA\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | GSIAValue\* |
| Def-GSIA | Default GSIA value | Com | Any | NonUpStrm | 1.0 |

**Spillage Rate**

Spillage rate will also be applied to measures however the values will not be tracked in the workpapers. The spillage rate will be tracked in an external table to be supplied to the Energy Division.

**READi Technology Fields**

This is a Non-DEER measure, and READi Technology Fields do not apply.

### 1.4.2 Codes and Standards Analysis

Title 24 (2013) includes some content related to non-residential package and split HVAC systems, which are the target system types for this measure. However, these requirements do not directly affect the fan belt or its operating characteristics and thus do not impact the assumptions that quantify the demand reduction and energy savings methodologies for each measure. Title 24 does not deal with maintenance issues. HVAC contractors should be licensed by the California State Licensing Board (CSLB) and the HVAC technicians should be EPA certified. Under state code, performance of maintenance and repairs does not require a building and/or job permit.

Table 5 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2008) | N/A | N/A |
| Title 20 (2010) | N/A | N/A |
| Title 24 (2013) | N/A | N/A |

### 1.4.3 Non-DEER Study Review

The efficiency improvement is a conservative estimate based on an engineering review of research literature as shown in Table 6. This is in agreement with USDOE’s assessment of the same literature as shown in their Motor Systems Tips #5 [E] where they suggest 2% as a median value for fan system efficiency improvement in HVAC systems with Type A and Type B cogged v-belts only.

Table Fan System Efficiency Improvement

|  |  |
| --- | --- |
| **Reference Source** | **Range of Efficiency Improvement** |
| [A] | 3% |
| [B] | 3% |
| [C] | 1% to 2% |
| [D] | 0.4% to 4.8% |
| [E] | 2% |
| Consensus Median | 2% |

### 1.4.4 Measure and Base Case Effective Useful Life

DEER14 update documentation provides EUL and RUL information to be used for the 2015 program cycle extension on [www.deeresources.com](http://www.deeresources.com). The DEER documentation “Summary of EUL-RUL Analysis for the April 2008 Update to DEER” provides the RUL value as a flat 1/3 of the EUL value. The RUL value will only be applied to the first baseline period for retrofit measures that have applicable code that will affect the energy savings. In all other installation types and retrofit with no applicable code that affects the energy savings, the RUL is not applicable to either the first or second baseline period.

However, it does not apply to fan v-belt life. A v-belt has a life based on fan run hours which varies by building type based primarily on occupancy schedule because the fans have to run continuously during all occupied hours. The supply and return fans will also run a few hours during unoccupied hours for heating and cooling as needed. Unoccupied fan hours for cooling are essentially zero in southern California due to thermostat set up and the major reduction in internal cooling loads (appliances off, lighting reduced to emergency only, and no people). In spite of thermostat setbacks, unoccupied fan hours for heating can be significant in cold climates since internal heat gains are small. In most SCE climate zones the majority of non-residential buildings have a low heating requirement. Therefore, the fan belt life can be based on the occupancy schedule.

*Equation 1 EUL = Belt Life / Occupancy Hours per year*

*Where:*

*Belt Life is 24,000 hours [A]*

*Occupancy Hours per year from Table 4 below.*

The EUL for the measure is 24,000 hours divided by the annual hours from the eQUEST run report “SS-L Fan Energy/Hours”.

# Section 2. Energy Savings & Demand Reduction Calculations

Energy savings and demand reduction were estimated by performing eQUEST [G] simulations. This is because these are non-DEER measures. The simulations used the DEER prototypes described in Section 1.4.1 as the baseline case. Keyword changes were then completed to simulate an improvement in fan system efficiency, and corresponding reduction in fan heat added to the airstream.

### Energy Simulation with eQUEST

eQUEST is a DOE2[[2]](#footnote-2) based simulation software package used to produce estimates of energy use of prototype non-residential building models. The DEER non-residential prototypes were simulated using eQUEST-3.64, consisting of 19 different building types. The 19 non-residential building types were simulated with three different HVAC unit types: AC Only, Gas Packs, and Heat Pumps. The only building type that does not have all three HVAC unit types available through MASControl is the “Education – Relocatable Classroom” which did not have a heat pump prototype. All 19 DEER non-residential building types are below in Table 7 with an “X” indicating when the building type was simulated with the corresponding HVAC unit type. The AC Only unit type was not directly simulated, instead using the results from the Gas Pack simulations and ignoring the therm energy use.

Table DEER Prototype Non-residential Building Types Simulated per HVAC Type

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building  Type** | **Abbreviated Building Types** | **AC Only** | **Gas Pack** | **Heat Pump** |
| Assembly | Asm | **X** | **X** | **X** |
| Education - Community College | ECC | **X** | **X** | **X** |
| Education - Primary School | EPr | **X** | **X** | **X** |
| Education - Relocatable Classroom | ERC | **X** | **X** |  |
| Education - Secondary School | ESe | **X** | **X** | **X** |
| Education - University | EUn | **X** | **X** | **X** |
| Health/Medical - Hospital | Hsp | **X** | **X** | **X** |
| Lodging - Hotel | Htl | **X** | **X** | **X** |
| Manufacturing - Bio/Tech | MBT | **X** | **X** | **X** |
| Manufacturing - Light Industrial | MLI | **X** | **X** | **X** |
| Health/Medical - Nursing Home | Nrs | **X** | **X** | **X** |
| Office - Large | OfL | **X** | **X** | **X** |
| Office - Small | OfS | **X** | **X** | **X** |
| Restaurant - Fast-Food | RFF | **X** | **X** | **X** |
| Restaurant - Sit-Down | RSD | **X** | **X** | **X** |
| Retail - Multistory Large | Rt3 | **X** | **X** | **X** |
| Retail - Single-Story Large | RtL | **X** | **X** | **X** |
| Retail - Small | RtS | **X** | **X** | **X** |
| Storage - Conditioned | SCn | **X** | **X** | **X** |

The 19 prototypes were simulated for each of the six non-residential vintages shown in Table 8 below. Each vintage has a different cooling load and may have different building and system component properties based either on code or standard practice at the time.

Table DEER Prototype Non-residential Vintages

|  |  |
| --- | --- |
| **Vintage** | **Years Represented** |
| Vintage 75 | Before 1978 |
| Vintage 85 | 1978 to 1992 |
| Vintage 96 | 1993 to 2001 |
| Vintage 3 | 2002 to 2005 |
| Vintage 7 | 2006 to 2011 |
| Vintage 11 | After 2011 |

Each of the building prototypes were run through eQUEST with the 16 CZ2010 (i.e. DEER 2014)[[3]](#footnote-3) weather files as shown in Table 9 below.

Table Weather Files

|  |  |  |
| --- | --- | --- |
| **California Climate Zone** | **Weather File Name** | **Representative City** |
| CZ-01 | cz01.bin | Arcata |
| CZ-02 | cz02.bin | Santa Rosa |
| CZ-03 | cz03.bin | Oakland |
| CZ-04 | cz04.bin | Sunnyvale |
| CZ-05 | cz05.bin | Santa Maria |
| CZ-06 | cz06.bin | Long Beach |
| CZ-07 | cz07.bin | San Diego |
| CZ-08 | cz08.bin | El Toro |
| CZ-09 | cz09.bin | Burbank |
| CZ-10 | cz010.bin | Riverside |
| CZ-11 | cz011.bin | Red Bluff |
| CZ-12 | cz012.bin | Sacramento |
| CZ-13 | cz013.bin | Fresno |
| CZ-14 | cz014.bin | China Lake |
| CZ-15 | cz015.bin | El Centro |
| CZ-16 | cz016.bin | Mount Shasta |

To simulate the HVAC Fans Cogged V-Belt Replacement measure in eQUEST, keyword values were changed to represent an improvement in fan efficiency and the corresponding reduction of fan heat entering the air stream. Table 10 indicates the required keyword(s) values to change per each HVAC system in the prototype model:

Table List of Modified eQUEST Keywords

|  |  |
| --- | --- |
| **HVAC Unit Type** | **Keyword** |
| Gas Pack | SYSTEM:SUPPLY-KW/FLOW |
| Gas Pack | SYSTEM:SUPPLY-DELTA-T |
| Heat Pump | SYSTEM:SUPPLY-EFF |

The base case for each DEER non-residential prototype model requires no changes to the existing keyword values.

The HVAC Fans Cogged V-Belt Replacement measure case for prototypes with Gas Pack units used the following calculations to obtain the measure case value:

*Measure Case SYSTEM:SUPPLY-KW/FLOW = Base Case SYSTEM:SUPPLY-KW/FLOW \* 1.02*

*Measure Case SYSTEM:SUPPLY-DELTA-T = Measure Case SYSTEM:SUPPLY-KW/FLOW \* 3060*

The HVAC Fans Cogged V-Belt Replacement measure case for prototypes with Heat Pump units used the following calculations to obtain the measure case value:

*Measure Case SYSTEM:SUPPLY-EFF = Base Case SYSTEM: SUPPLY-EFF \* 1.02*

## 2.1 Electric Energy Savings Estimation Methodologies

The calculation of electric energy use for the base case and measure case followed the methodology discussed in Section 2.0. The savings for the HVAC Fans Cogged V-Belt Replacement measure are estimated as follows.

*Fan Energy Savings [kWh/ton-year] = Base Case Annual Fan Energy Use – Measure Case Annual Fan Energy Use*

*Where:*

*Base Case Annual Fan Energy Use = Output from eQUEST runs*

*Measure Case Annual Fan Energy Use = Output from eQUEST runs*

Table Cogged V-belt Energy Savings for Gas Packs & Unitary AC-Only (kWh/ton)



Table Cogged V-belt Energy Savings for Heat Pump (kWh/ton)



### Base Case

The base case is the existing system as described by the unmodified DEER prototype models as described in Section 1.4.1 DEER Measure and Base Case Analysis.

## 2.2. Demand Reduction Estimation Methodologies

The electric demand reduction for the HVAC Fans Cogged V-Belt Replacement measure are estimated as follows.

*Fan Demand Reduction [kW/ton-year] = Base Case Peak Demand – Measure Case Peak Demand*

*Where:*

*Base Case Peak Demand = Output from eQUEST runs*

*Measure Case Peak Demand = Output from eQUEST runs*

Table Cogged V-belt Peak Demand Reduction for Gas Packs & Unitary AC-Only (kW/ton)



Table Cogged V-belt Peak Demand Reduction for Heat Pump (kW/ton)



## 2.3. Gas Energy Savings Estimation Methodologies

The HVAC Fan Cogged V-Belt Replacement measure has little or no impact on gas energy usage.

# Section 3. Load Shapes

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the DEER: HVAC\_Split-Package\_AC load shape. See Table 15 Building Types and Load Shapes for a list of all Building Types and Load Shapes. A more thorough discussion regarding the load shapes for this measure is available [31]. The closest load shape chosen is indicated below:

Table Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **E3 Alt. Building Type** | **Load Shape** |
| All | NON\_RES | DEER: HVAC\_Split-Package\_AC |

# Section 4. Base Case & Measure Costs

This work paper does not report base case and measure costs for SCE as those costs are between the program and their contractors for direct install programs. The remaining cost data is for PG&E.

|  |  |  |  |
| --- | --- | --- | --- |
| **Install/Program Type** | **Measure Life Basis** | **First Baseline Period Gross Measure Cost (RUL)** | **Second Baseline Period Gross Measure Cost (EUL – RUL)** |
| ROB | EUL | Calculated as Incremental Measure Cost | N/A |

## 4.1 Base Case(s) Costs

The following Transaction type is appropriate to this measure. The Base Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Transaction** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Base Case Cost** |
|  | ROB | Industry Practice | $ 1.59 | $ 5.10 | $ - | $ 6.69 |

*All costs are noted as $ per measure unit*

Costs were calculated from information from industry sources. It is assumed that the majority of units serviced will be 6 tons or under. Costs were provided for the most common models by field service technicians, using pricing per <http://aaa-electric.net/>.

See *Notched and Regular Belt Price Comparison*14 for details.

## 4.2 Measure Case Costs

The following Transaction type is appropriate to this measure. The Measure Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Transaction** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Base Case Cost** |
|  | ROB | Industry Practice | $ 1.98 | $ 5.10 | $ - | $ 7.08 |

*All costs are noted as $ per measure unit*

Costs were calculated from information from industry sources. It is assumed that the majority of units serviced will be 6 tons or under. Costs were provided for the most common models by field service technicians, using pricing per <http://aaa-electric.net/>

. See *Notched and Regular Belt Price Comparison*14 for details.

## 4.3 Incremental & Full Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Install/Program Type** | **Gross Measure Cost** | **Gross Measure Cost** | **Incremental Measure Cost** |
|  | (RUL Period/First Baseline) | (EUL-RUL Period/ Second Baseline) |  |
| **ROB** | **Measure Equipment Cost – Base Case Equipment Cost** | **N/A** | **Measure Equipment Cost – Base Case Equipment Cost** |

### 4.3.1 Gross Measure Cost

Gross Measure Cost is the cost to install an energy efficient measure per the CPUC calculators. This definition implies a different meaning depending on the install type.

This measure transaction type is **ROB**, so the Gross Measure Cost (GMC) is represented by the equation below:

*GMC = (Measure Equipment Cost + Measure Labor Cost) –*

*(Base Case Equipment Cost + Base Case Labor Cost)*

\*Note: We assume that, unless stated otherwise, the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

GMC = Measure Equipment Cost – Base Case Equipment Cost

*GMC = $ per (unit) - $ per (unit) = $ per unit*

\*Note: Various complicated price fluctuations are not addressed in these equations, such as future costs due to inflation in labor, future costs due to deflation in material cost, and other variables that cannot be accurately described at this time.

### 4.3.2 Incremental Measure Costs

Incremental Measure Cost is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. While IMC has a straightforward definition depending on the install type, the equation does vary.

This measure transaction type is **ROB** so the Gross Measure Cost (GMC) is represented by the equation below:

*IMC = (Measure Equipment Cost + Measure Labor Cost) –*

*(Base Case Equipment Cost + Base Case Labor Cost)*

\*Note: Unless stated otherwise the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

IMC = Measure Equipment Cost – Base Case Equipment Cost

*IMC = $ per (unit) -- $ per (unit) = $ per (unit)*

Summary Table for Section 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure ID** | **Transaction Type** | **Base Case Total Cost** | **Measure Case Total Cost** | **Gross Measure Case Cost** | **Incremental Measure Cost** |
|  | ROB | 6.69 | $ 7.08 | $ 7.08 | $ 0.39 |

# Attachments

The measure calculation spreadsheets are attached here.







# References

1. Jim Cole, "Summary of Findings of CIEE Technology Assessment of Energy-Efficient Belt Transmission," Cogged V-belts typical efficiency improvement of 3%... University of California Berkeley, Memorandum, August 17, 1994. Attached paper by Almeida, Anibal De, University of Coimbra, and Steve Greenberg, Lawrence Berkeley laboratory.
2. "Gates Corporation Announces New EPDM Modeled Notch V-belts, June 2010 (Assumed 3% efficiency improvement) http://www.gates.com/news/index.cfm?id=11296$show=newsitem&location \_id=753&view=Gates
3. Ula, Sadrul, Larry E. Birnbaum, Don Jordan, "Energy Efficient Drivepower: An Overview," Electrical Engineering Dept, University of Wyoming, for Bonneville Power Administration, (1% to 2% page 33).
4. "Energy Loss and Efficiency of Power Transmission Belts," Advanced Engineering Research, Belt Technical Center, Carlisle Power Transmission Products, Third Work Energy Engineering Congress, Association of Energy Engineers, 1977. (Conclusion: "…classical B-section cogged belts ...demonstrated the largest energy savings, ranging from 3 to 6 percent."
5. Motor System Tip Sheet #5, Replace V-belts with Cogged or Synchronous Belt Drives,” USDOE-EERE, September 2005. (Specified 2% based on review of same references) <http://www1.eere.energy.gov/industry/bestpractices/pdfs/replace_vbelts_motor_systemts5.pdf>
6. Grainger catalog on-line web-site for Dayton V-belt pricing <http://www.grainger.com/Grainger/ecatalog/N-1z0r596/Ntt-V-belts>
7. eQUEST – building energy use and cost analysis software, developed by James J. Hirsch & Associates, version 3.64.



1. www.deeresources.com [↑](#footnote-ref-1)
2. www.doe2.com [↑](#footnote-ref-2)
3. www.deeresources.com [↑](#footnote-ref-3)