Sustainable approaches to the design, construction and operation of cleanrooms and critical environments

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ESC
ENVIRONMENTAL
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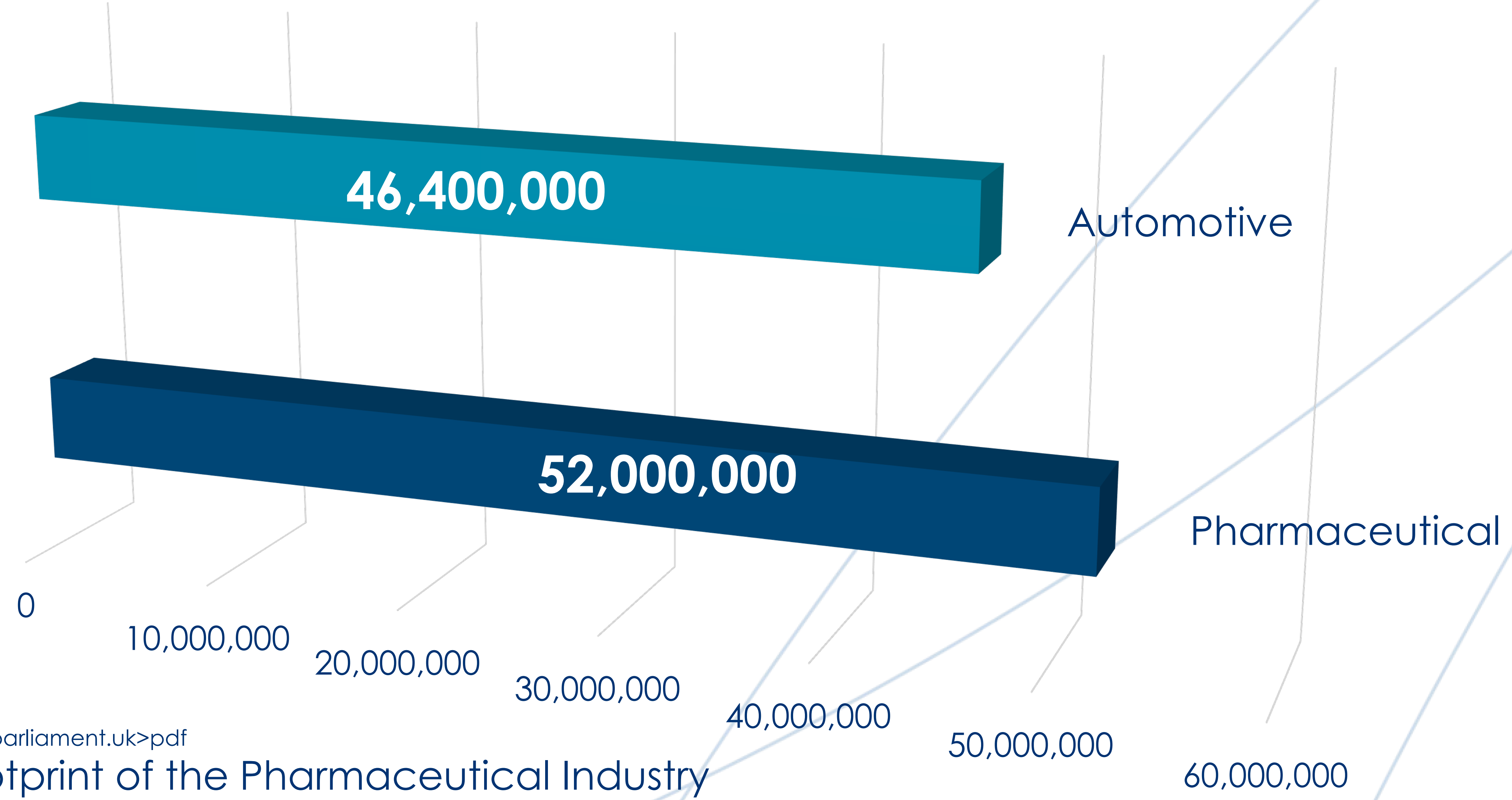
CREATING ENVIRONMENTS FOR SUCCESS

I am an **Optimistic**, **Resourceful**, **Idealist**, who influences through **story telling**, joining ESC in 2023.

Started my career in pharmaceutical design, commissioning and validation back in 2009 and quickly discovered my passion for the commercial side of the business.

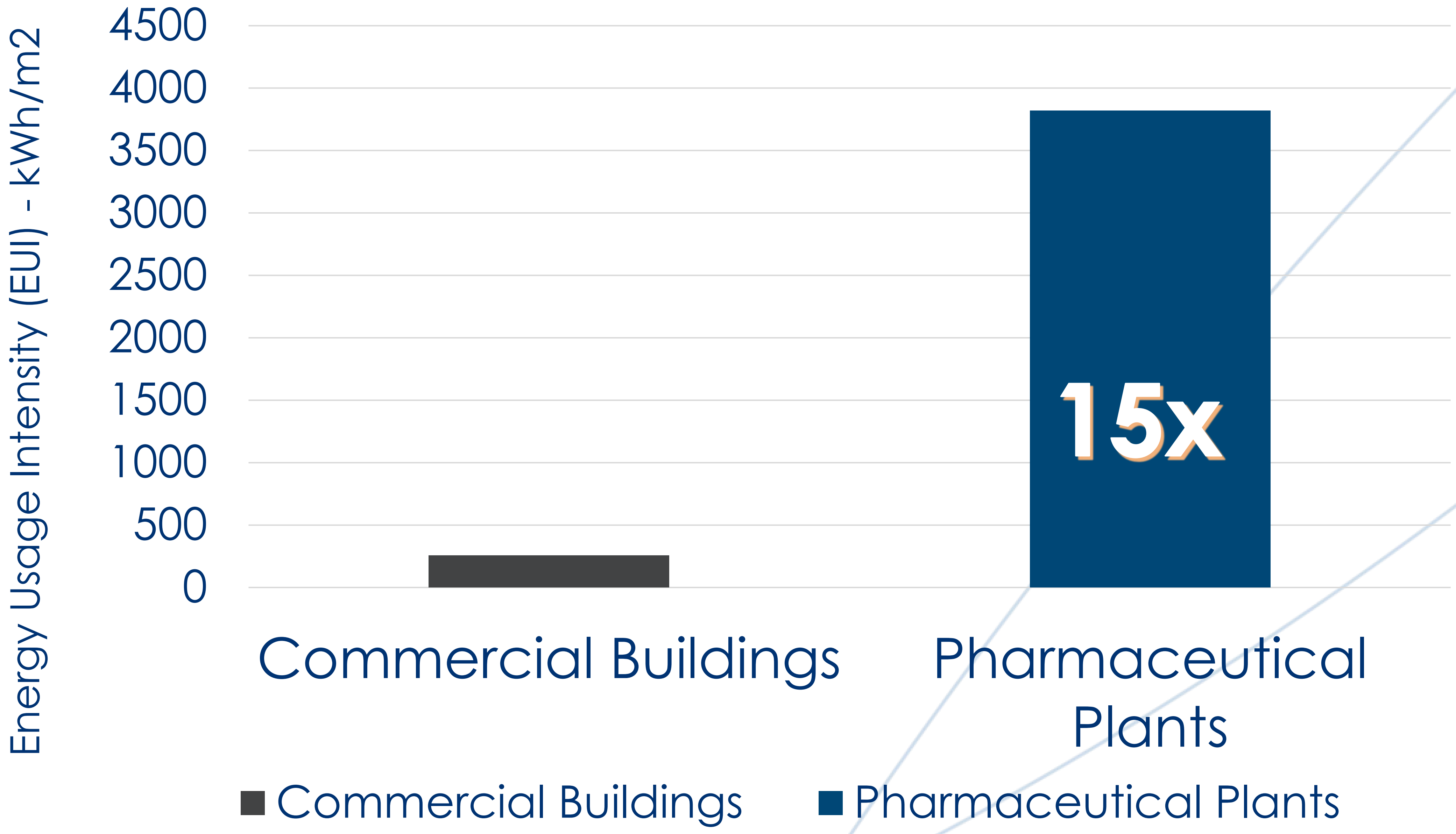
Millions of Tons of CO_2 Generated Manufacturing Globally

Pharmaceutical vs Automotive



UK Parliament
https://comimittees.parliament.uk>pdf
Carbon Footprint of the Pharmaceutical Industry

ENERGY USAGE INTENSITY



Source: Energy Benchmarking in the Pharmaceutical Industry (Josh Capparella)
Pharmaceutical Engineering Sept/Oct 2013, VOL 33, NO 5

Legacy vs. New Build

We can't solely rely on building new state of the art facilities
We must develop strategies that can be applied to legacy facilities

Reduction of Carbon Emissions of HVAC Systems: A Case Study of a Pharmaceutical Site in France

Abaubakry M'baye

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Reduction of Carbon Emissions of HVAC Systems: A Case Study of a Pharmaceutical Site in France

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Abstract Heating, ventilation and air conditioning systems (HVAC) are widely present in industry. They permit to maintain strict environmental conditions such as in clean room in pharmaceutical and aerospace industries. They also permit to maintain personal health and comfort (e.g., in offices). This article is a case study in an industrial pharmaceutical site in France. HVAC systems represent 57% of site's carbon emissions because air must be transported and undergo several different treatments: heating, cooling, dehumidification, and Filtration. Moreover, those systems are generally overdesigned, operate very far to the specification limits and/or regulation are not optimized. To minimize carbon emissions, a specific methodology has been developed for ensuring to make the right choices when implementing a new HVAC or modifying an existing one. This methodology contains 4 steps: reduce quantity of air, reduce air treatment periods, efficient air treatment by design and efficient air treatment by management. Each step includes complex, simple and innovative actions such as electronically commutated motor in place of conventional motor. The methodology developed does not degrade global performance and thermal efficiency of systems and answer to quality, environment, health, and safety requirements. The application of this methodology has permitted to reduce carbon emissions of HVAC systems by 24% in less than 3 years.

Keywords Carbon emissions reduction, HVAC, Methodology, Best practices, Energy efficiency

METHODOLOGY

Energy Usage By Category

Table 1. Electrical Consumption per Equipment/Process for 2018

Equipment/Process	2018 consumptions (kWh)
Compressed air	624 138
HVAC dehumidifiers	991 858
HVAC motors	2 494 617
Dust collectors	431 293
Hot water production	190 626
Chilled water production	1 608 581
Purified water	161 821
Lighting and sockets	708 608
Industrial ovens	14 148
Information Technology rooms (uninterruptible power supply and HVAC)	627 220
Warehouses (chargers, lighting, various)	99 150
Vacuum pumps	76 363
Process	635 399
Coating equipment	423 428
Kitchen	148 223
Fire extinction system	16 324
Site total consumption	**9 251 797**

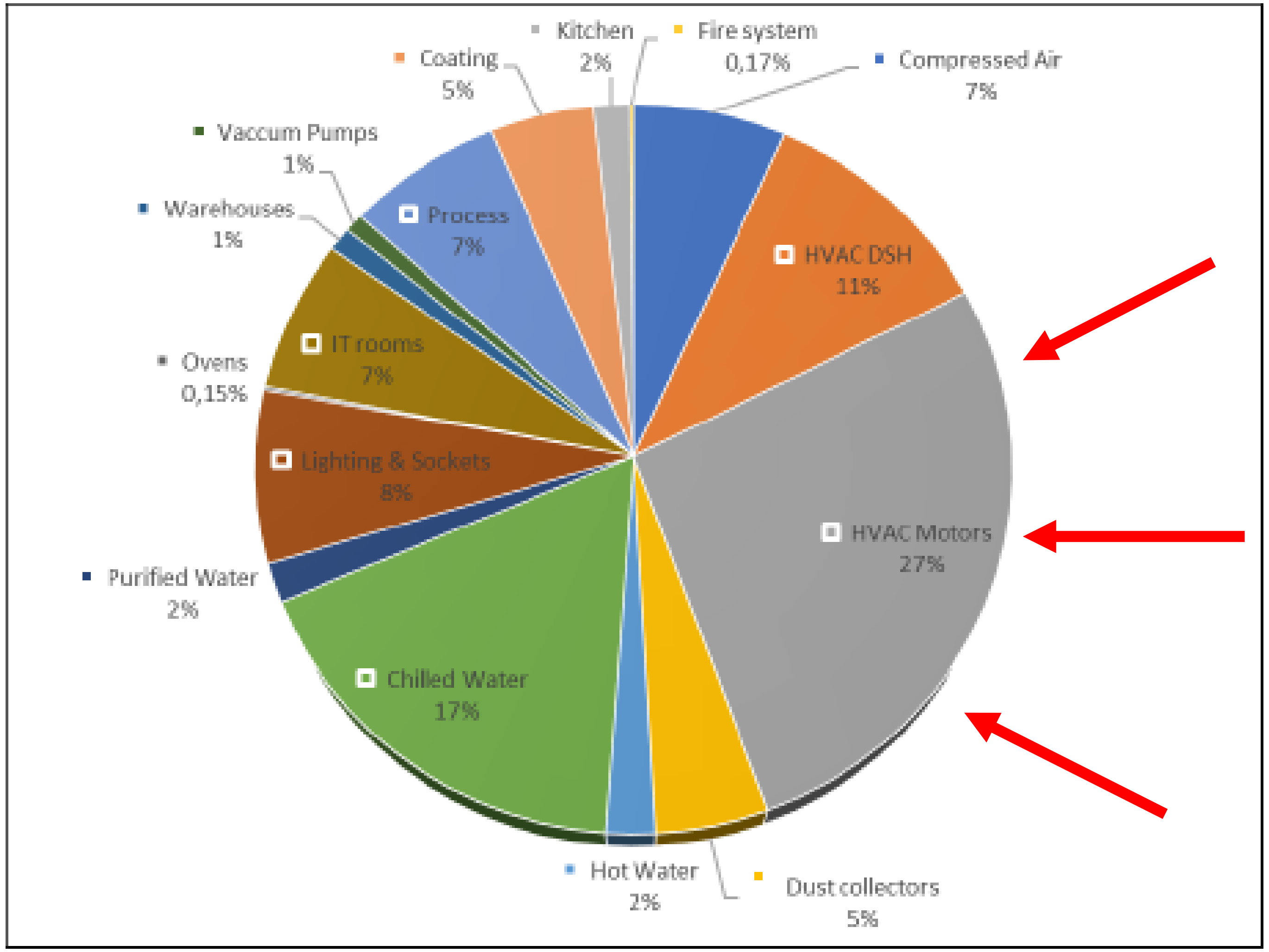


Figure 3. 2018 site's electrical consumption repartition in %

DESIGN - REDUCE VOLUMES, SPEEDS, PRESSSURE DROP

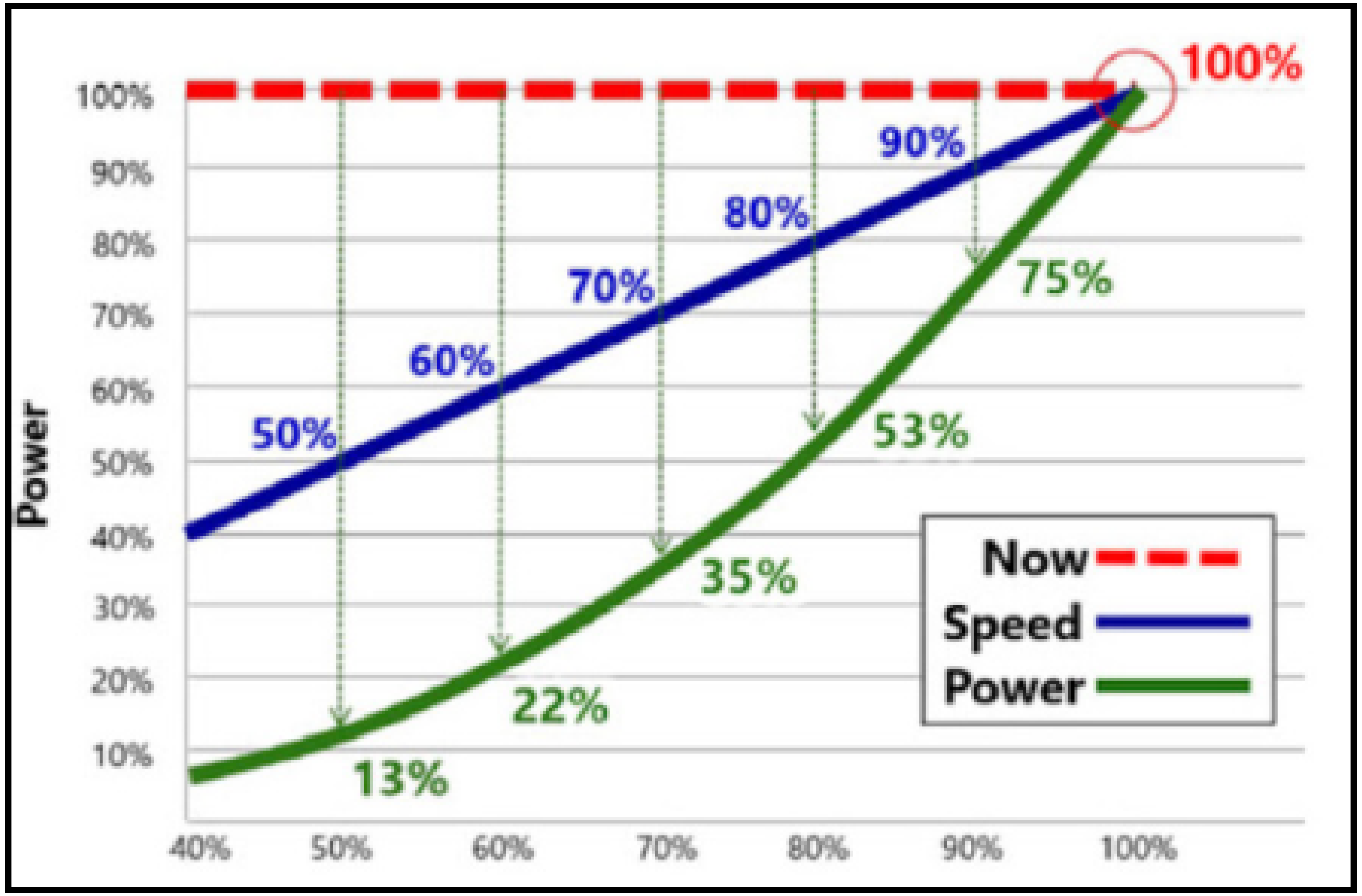
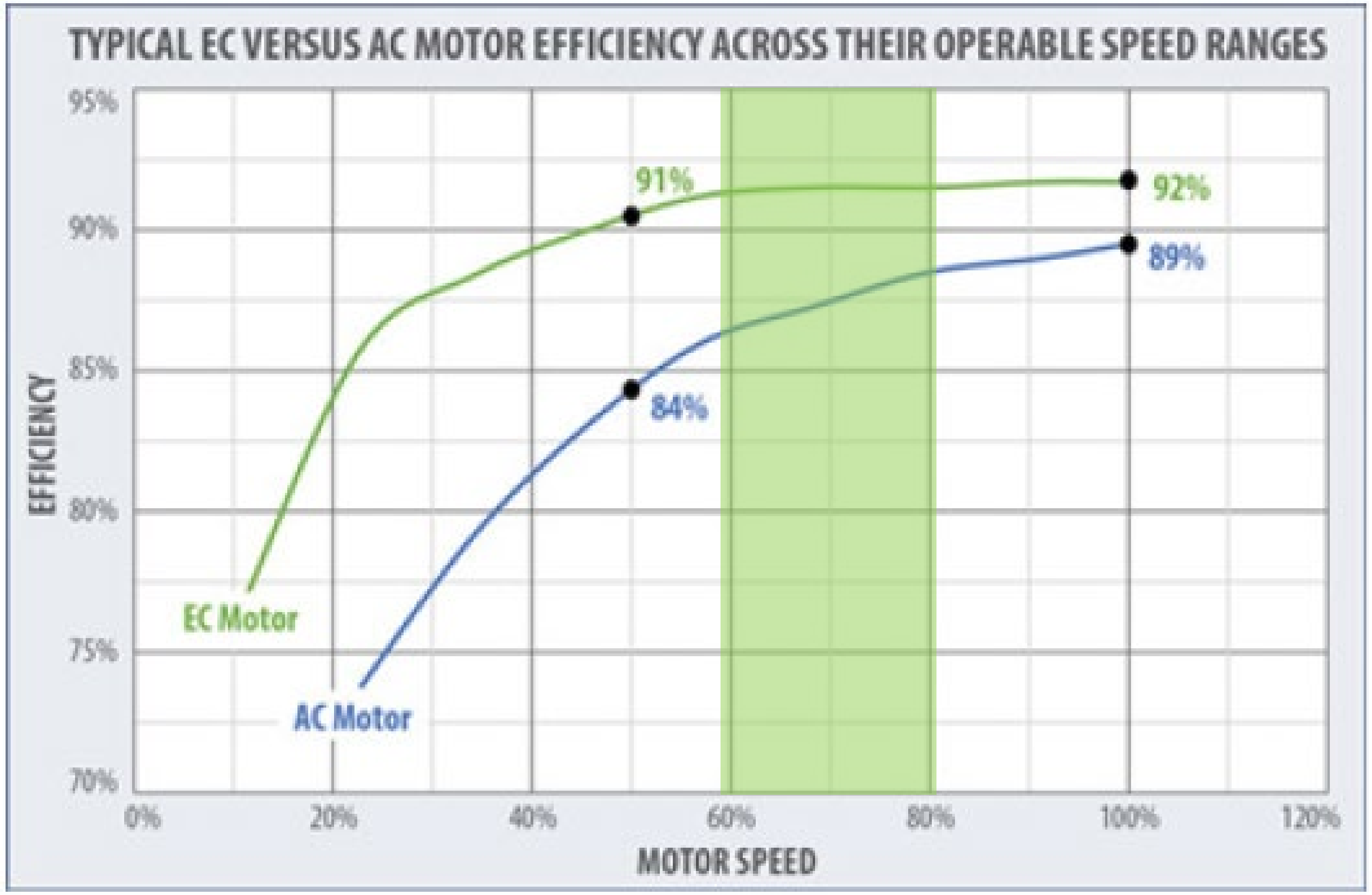
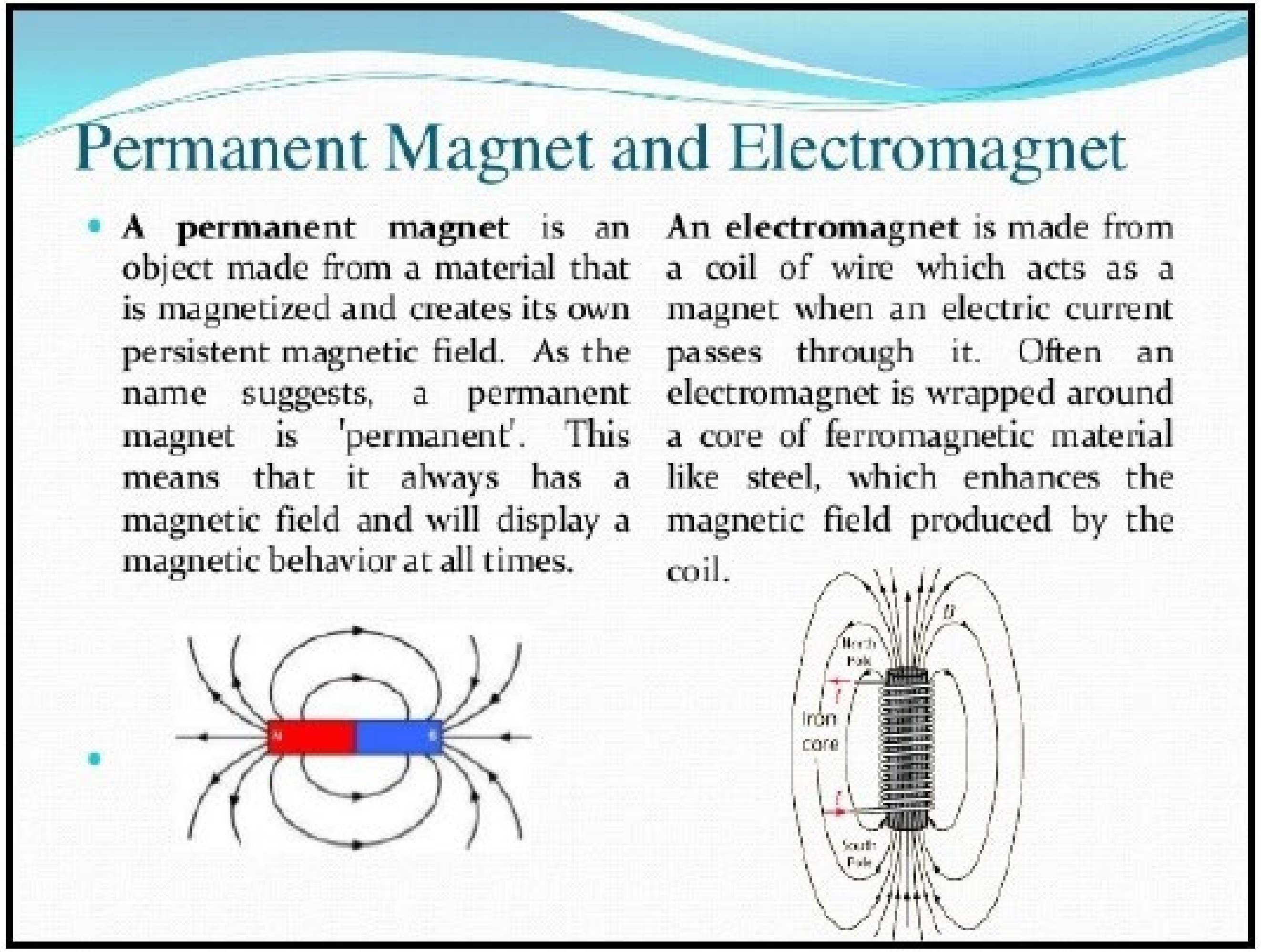


Figure 5. Affinity fan laws: Power and Air Flow [6]

EC vs AC Motor Fans





DESIGN - REDUCE VOLUMES, SPEEDS, PD

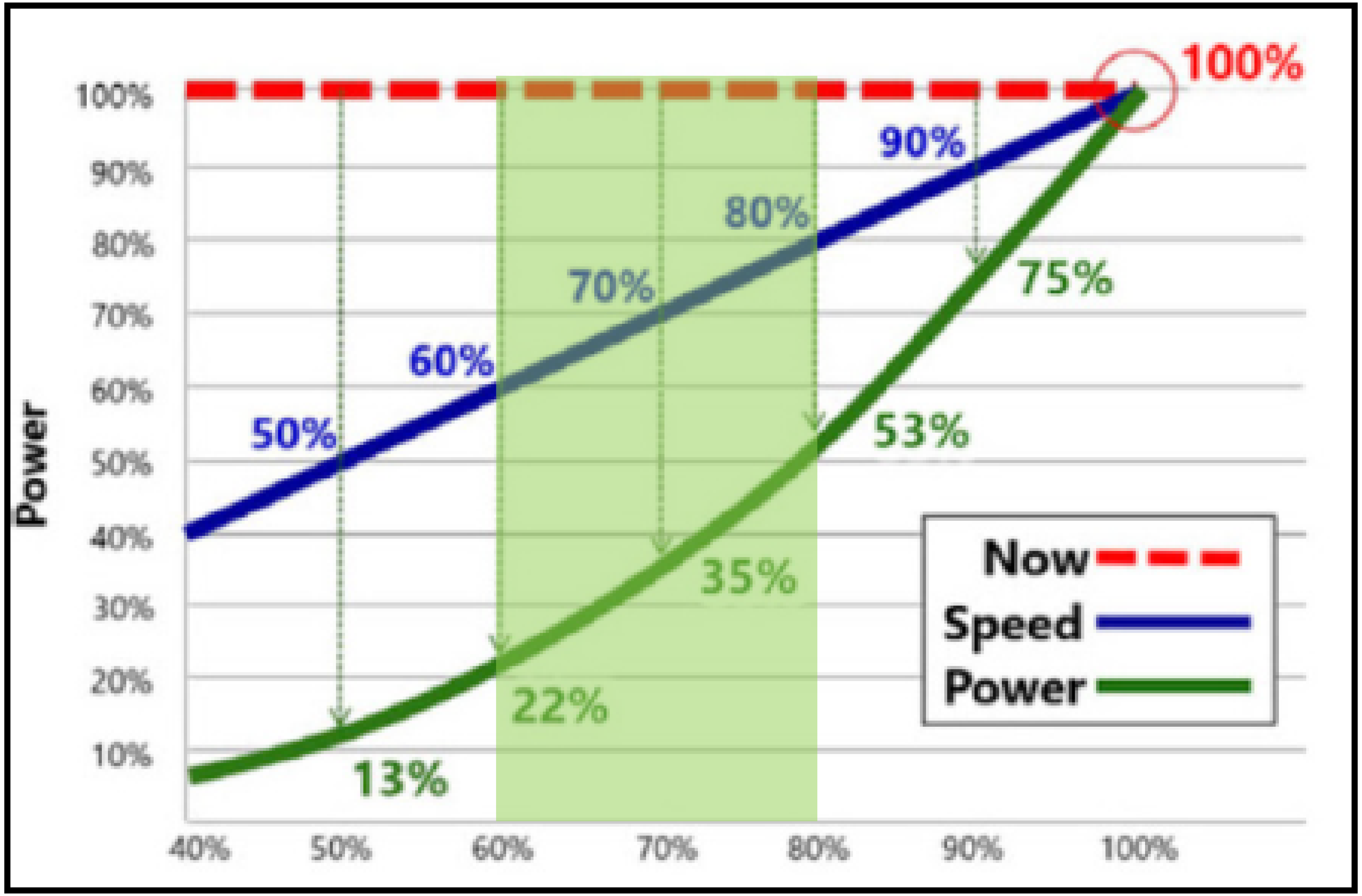
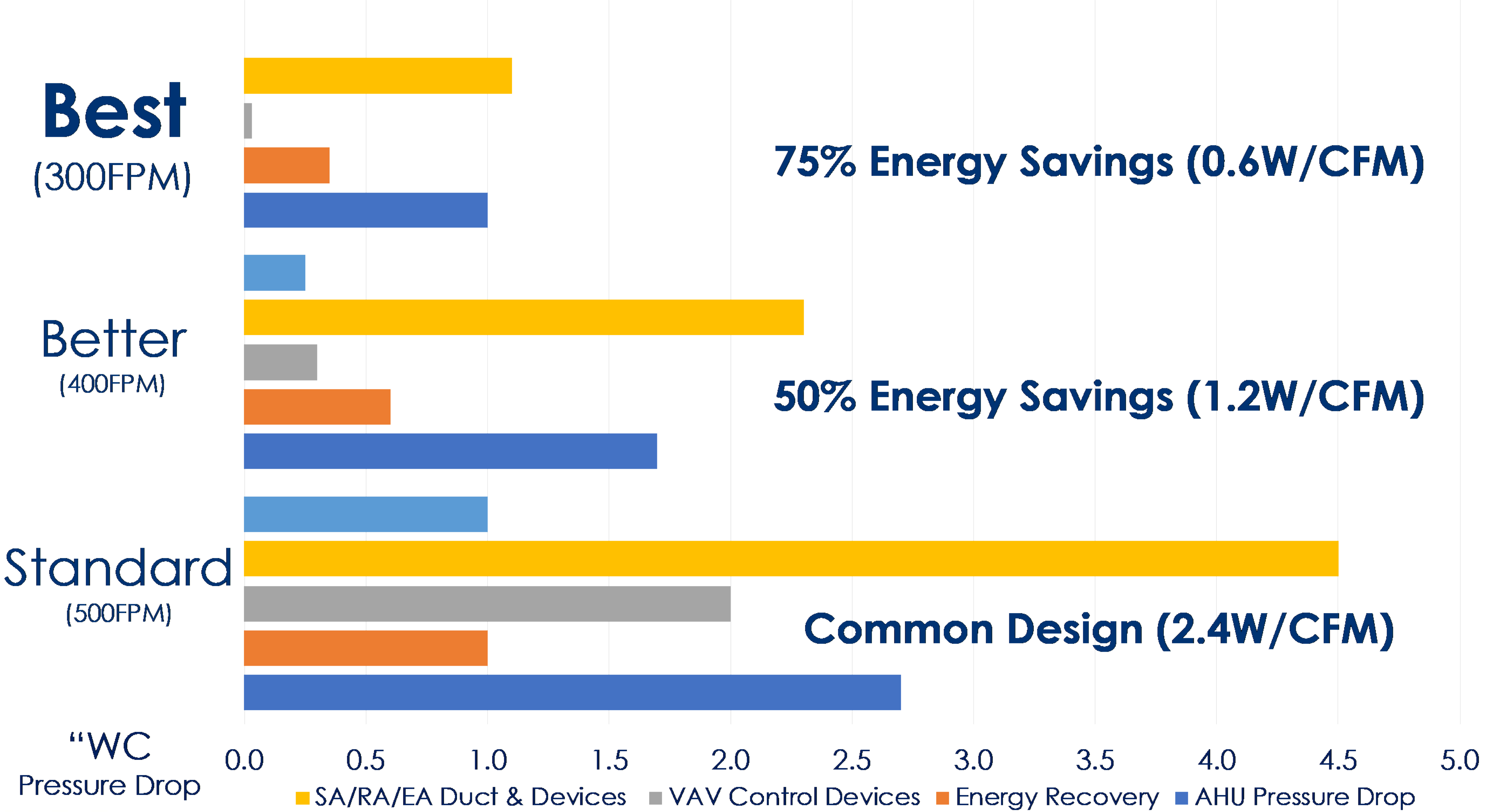


Figure 5. Affinity fan laws: Power and Air Flow [6]

The Importance of Face Velocity and Pressure Drop



Multiple Plug Centrifugal Fan Arrays w/EC Motors

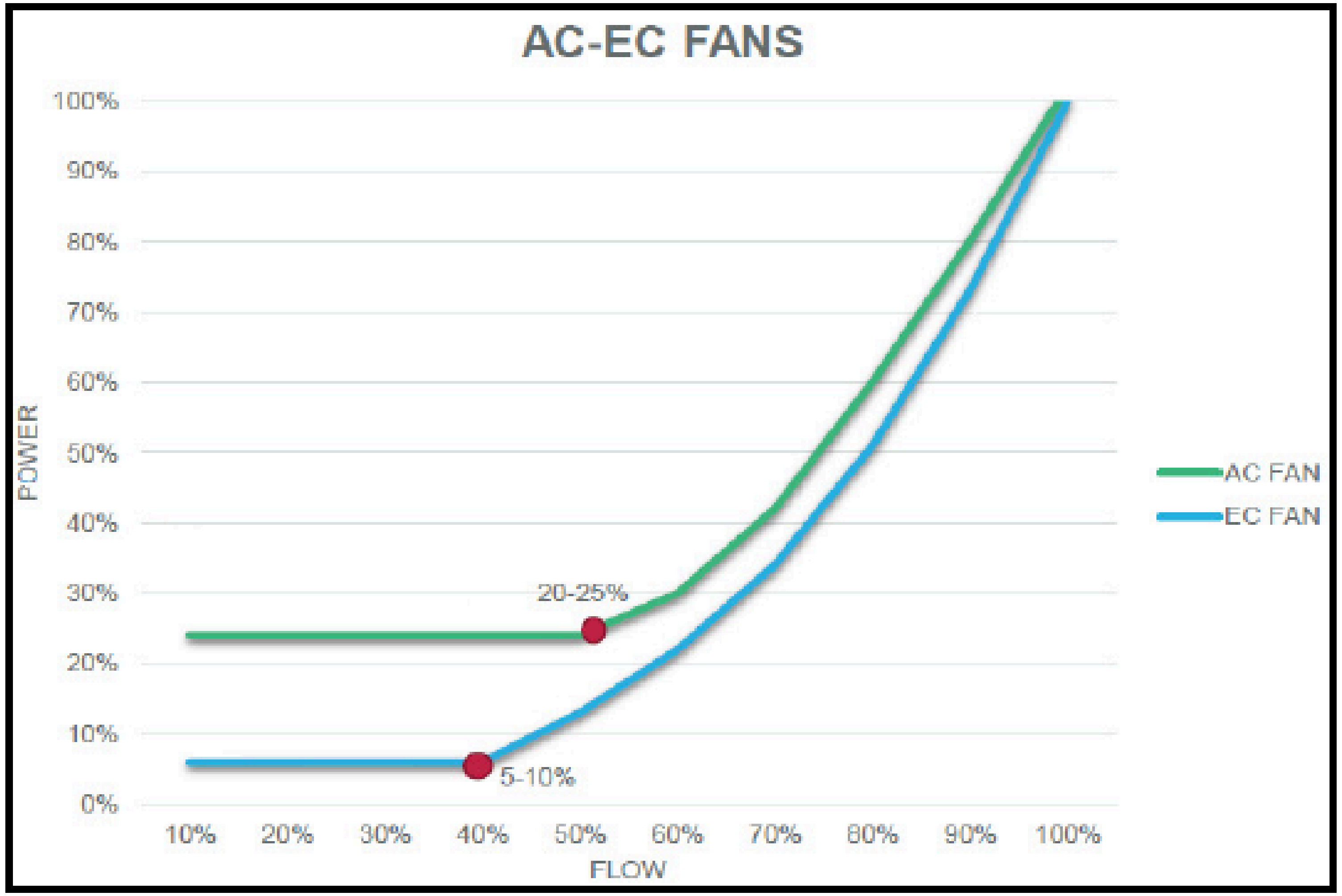


Figure 10. AC Fans vs EC Fans

FAN ENERGY 100% OUTSIDE AIR MAKE UP AIR UNIT

FAN ENERGY - 12,000 CFM MAKE UP AIR UNIT

LOW PRESSURE DROP @ 3.2” WC

LOWER PRESSURE DROP

2 Fans System kW 4.8 Annual kW 42,048	29% ENERGY LPD	21% ENERGY LPD + REDUNDANCY	3 Fans System kW 1.8 Annual kW 31,116
4 Fans System kW 16.7 Annual kW 146,012	100% ENERGY SPD BASE LINE	74% ENERGY SPD + REDUNDANCY	6 Fans System kW 12.3 Annual kW 107,748

STANDARD DESIGN @ 8” WC

N+1 REDUNDANCY

WATTS / CFM

LOW PRESSURE DROP @ 3.2" WC

LOWER PRESSURE DROP ⇧

2 Fans System kW 4.8 Annual kW 42,048	0.40	0.30	3 Fans System kW 3.6 Annual kW 31,116
4 Fans System kW 16.7 Annual kW 146,012	1.39	1.03	6 Fans System kW 12.3 Annual kW 107,748

STANDARD DESIGN @ 8" WC

N+1 REDUNDANCY ⇨

ANNUAL $ @ $ 0.12 / kW

LOW PRESSURE DROP @ 3.2” WC

2 Fans System kW 4.8 Annual kW 42,048	$5,046	$3,734	3 Fans System kW 3.6 Annual kW 31,116
4 Fans System kW 16.7 Annual kW 146,012	$17,521	$12,930	6 Fans System kW 12.3 Annual kW 107,748

⇧ LOWER PRESSURE DROP

STANDARD DESIGN @ 8” WC

N+1 REDUNDANCY ⇨

METRIC TONS CO_2 EQUIVALENT

LOW PRESSURE DROP @ 3.2" WC

LOWER PRESSURE DROP

2 Fans System kW 4.8 Annual kW 42,048 **29.4**	3 Fans System kW 3.6` Annual kW 31,116 **21.7**
4 Fans System kW 16.7 Annual kW 146,012 **102**	6 Fans System kW 12.3 Annual kW 107,748 **75.4**

STANDARD DESIGN @ 8" WC

N+1 REDUNDANCY

EQUIVALENT GASOLINE POWERED CARS @ YEAR

LOW PRESSURE DROP @ 3.2” WC

LOWER PRESSURE DROP

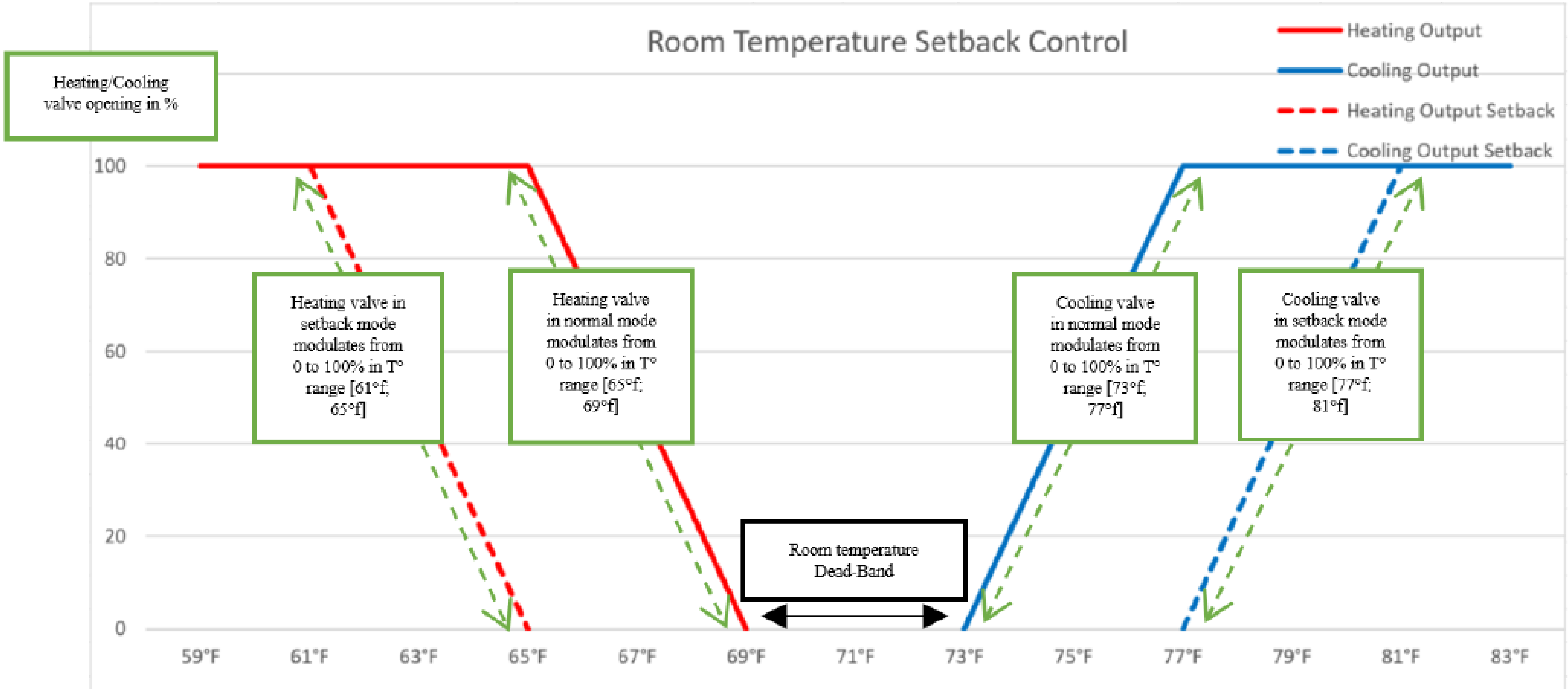
2 Fans System kW 4.8 Annual kW 42,048	7.0	6.0	3 Fans System kW 3.6 Annual kW 31,116
4 Fans System kW 16.7 Annual kW 146,012	24.3	18.0	6 Fans System kW 12.3 Annual kW 107,748

STANDARD DESIGN @ 8” WC

N+1 REDUNDANCY

Additional Measures

CONTROLS – REDUCE AIR TREATMENT PERIODS



CONTROLS – AIRFLOW SETBACKS

INTERNATIONAL STANDARD

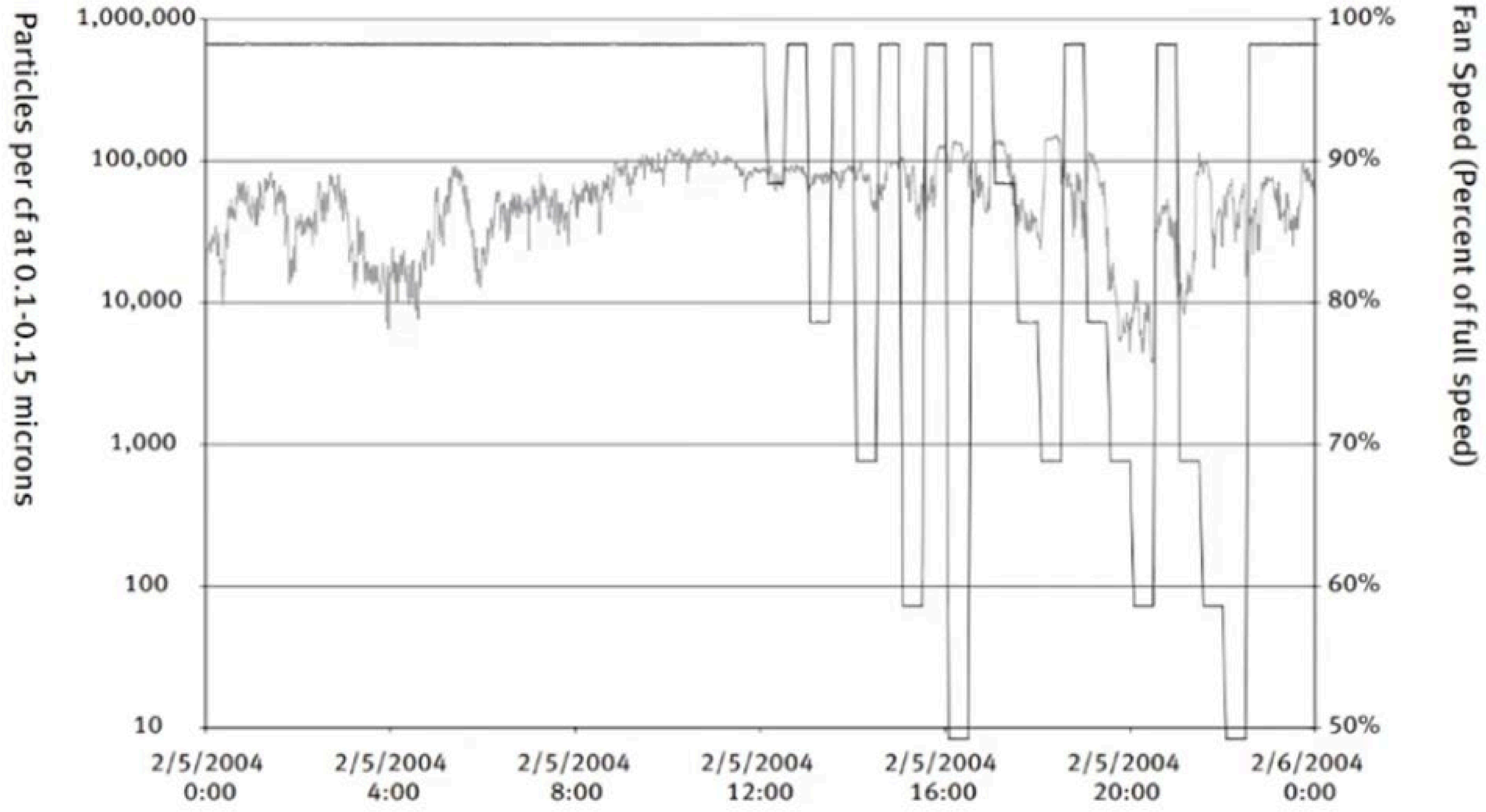
ISO 14644-16

First edition
2019-05

Cleanrooms and associated controlled environments —

Part 16:
Energy efficiency in cleanrooms and separative devices

Recommends to turn-down or even turn off airflow during non-operational hours



Source: Lawrence Berkeley National Laboratory Pilot Airflow Study

CONTROLS – LOOP TUNING

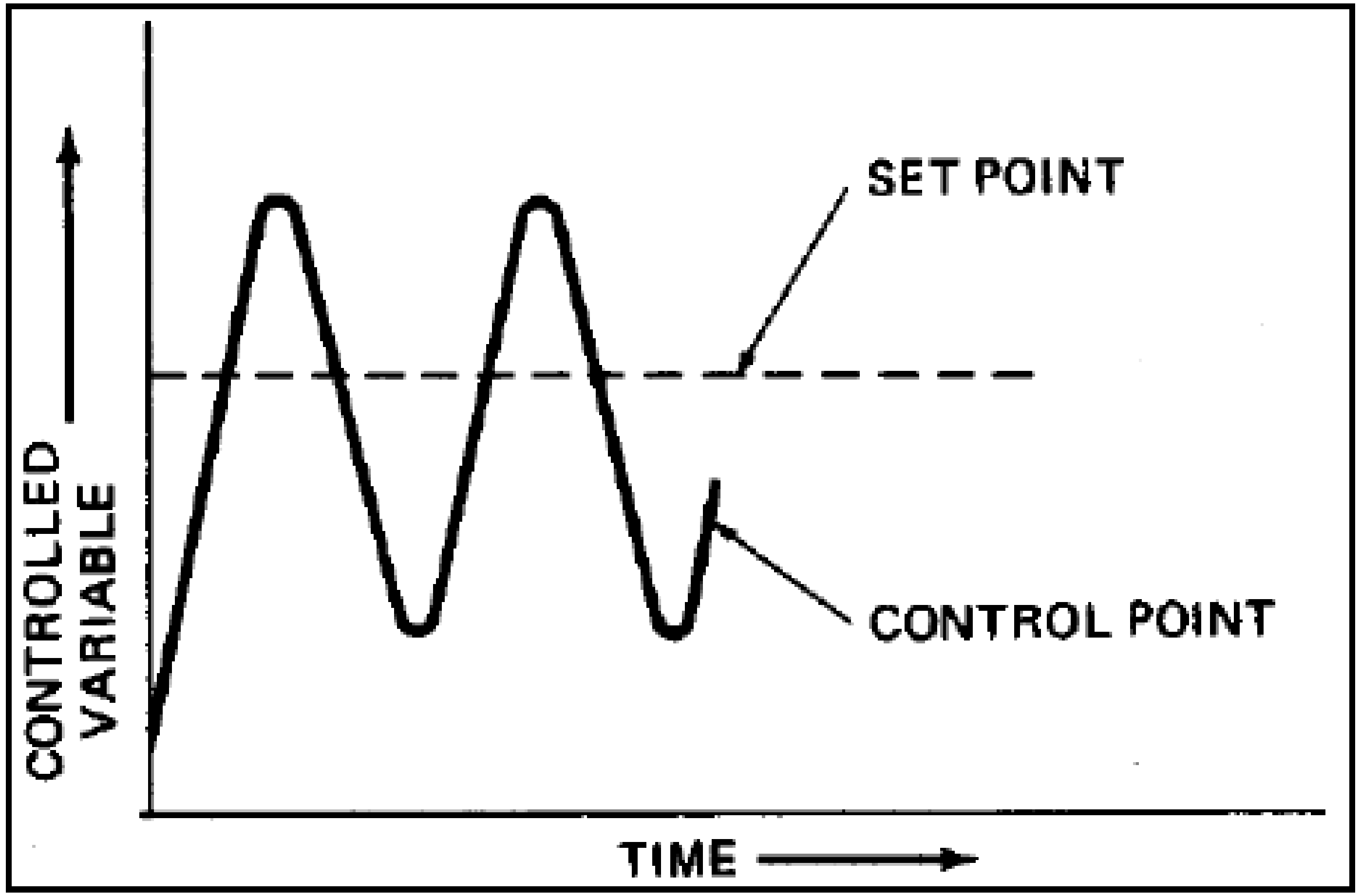


Figure 16. Poor variable control

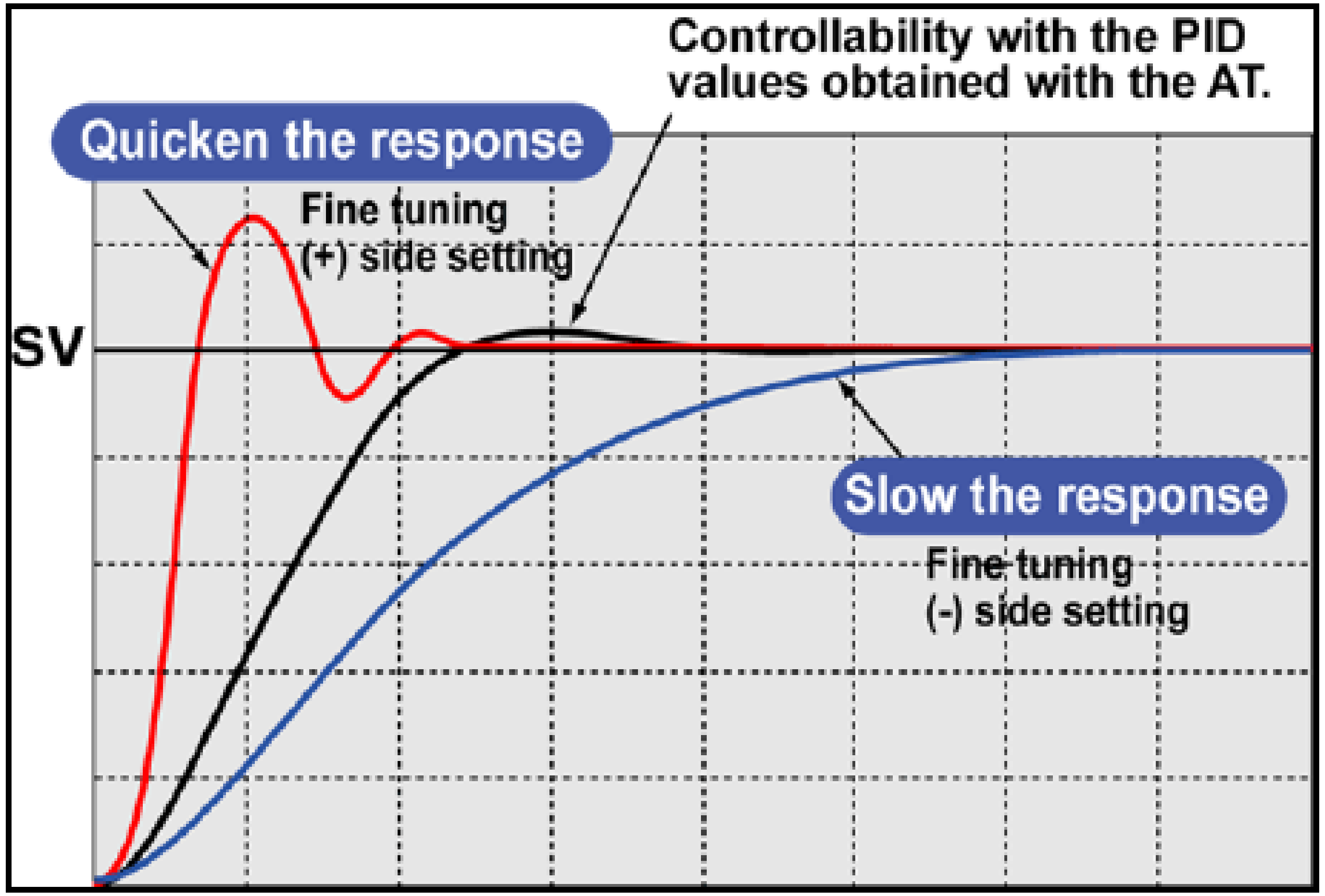
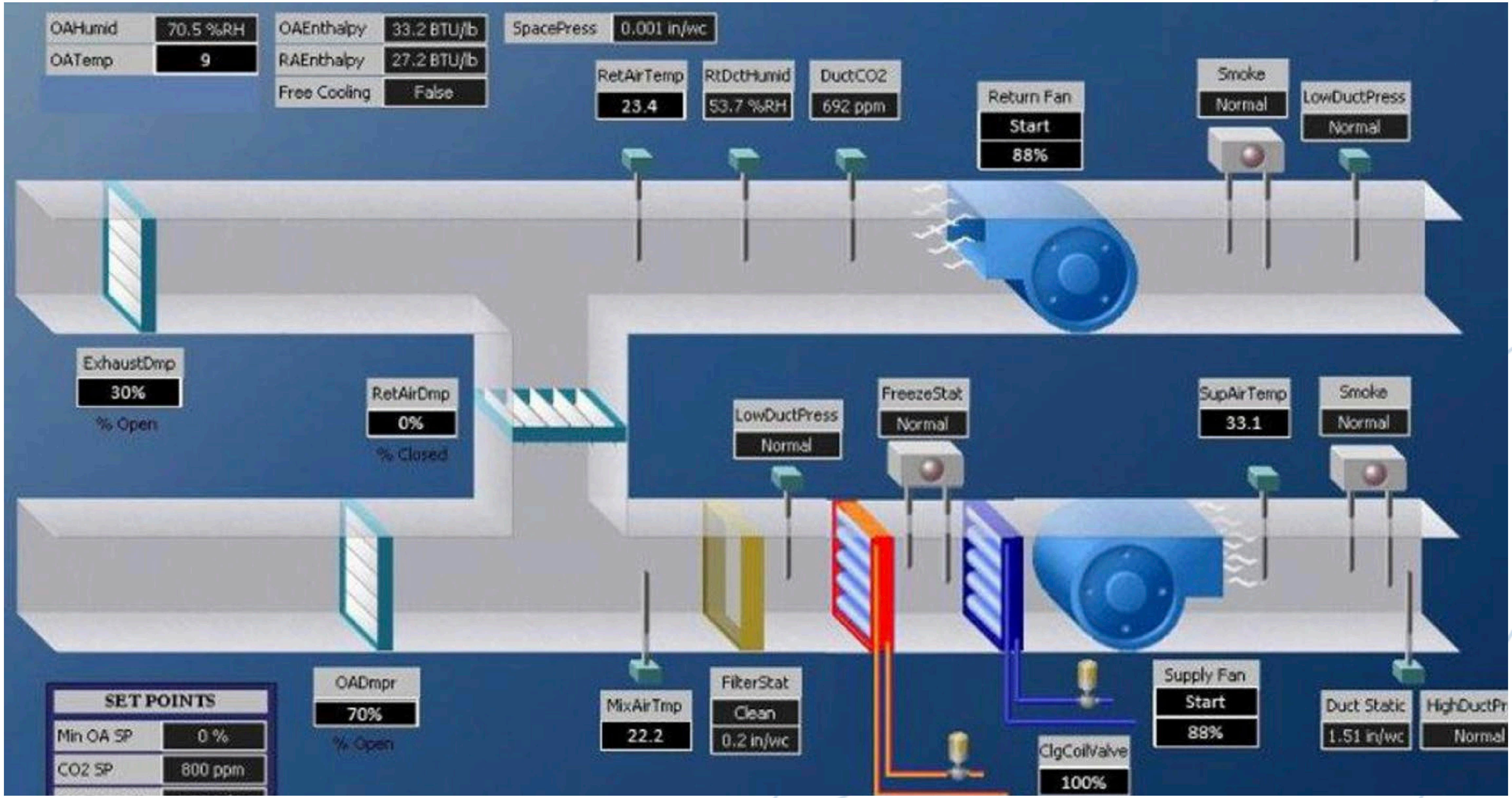


Figure 15. PID controls Loop

ADVANCED MONITORING AND BAS INTEGRATIONS



PROPER MAINTENANCE

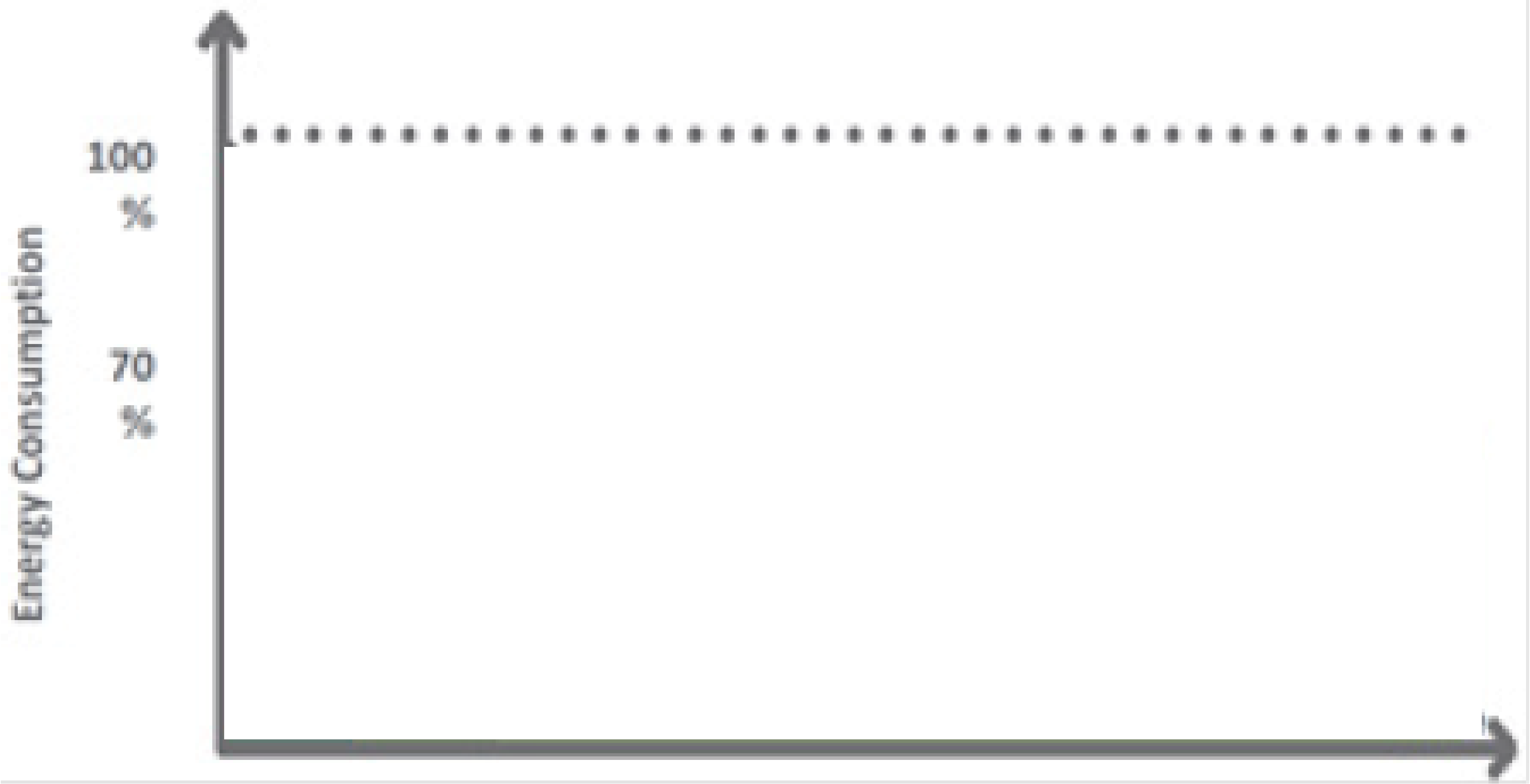


Figure 17. Energy management impact on consumption over time

RESULTS

Table 10. HVAC Electrical Consumption Evolution from 2018 to 2021

Electrical consumptions (kWh)	**2018**
HVAC Dehumidification	991 858
HVAC Motors	2 494 617
Chilled water production	1 608 581
Total	**5 095 056**

1 229 967 kWh in annual electrical savings

What can you do today?

- Find your air balance report, look at the amperage of your fans

- Calculate the kW to figure out watts/CFM
  - On a per AHU basis
  - If you're running around 0.6W/CFM you're close to maximum efficiency
  - If your running higher, you know opportunities exist to save money

Additional Considerations

- Do you have a method of varying supply air and return /exhaust air to maintain room differential pressure ?

- What is the heat load from equipment as this will determine minimum air flow ?

- Know the cooling and heating medium
  - Chilled and hot water/glycol are easier then DX cooling and indirect heating sources as they will require minimum airflow
  - CW may require looking at the control valves
  - Can the existing fans be replaced with fan arrays?

Part 2 – Embodied Carbon

What is Embodied Carbon?

What is Embodied Carbon? | Inflation Reduction Act | Grant Program | Tools & Resources | Label Program for Low Embodied Carbon Construction Materials

Embodied carbon—also known as embodied greenhouse gas (GHG) emissions—refers to the amount of GHG emissions associated with upstream—extraction, production, transport, and manufacturing—stages of a product's life. Many initiatives to track, disclose, and reduce embodied carbon emissions also consider emissions associated with the use of a product and its disposal.

EMBODIED CARBON WHITE PAPER

Toronto, Ontario
January 2018

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Urban Equation

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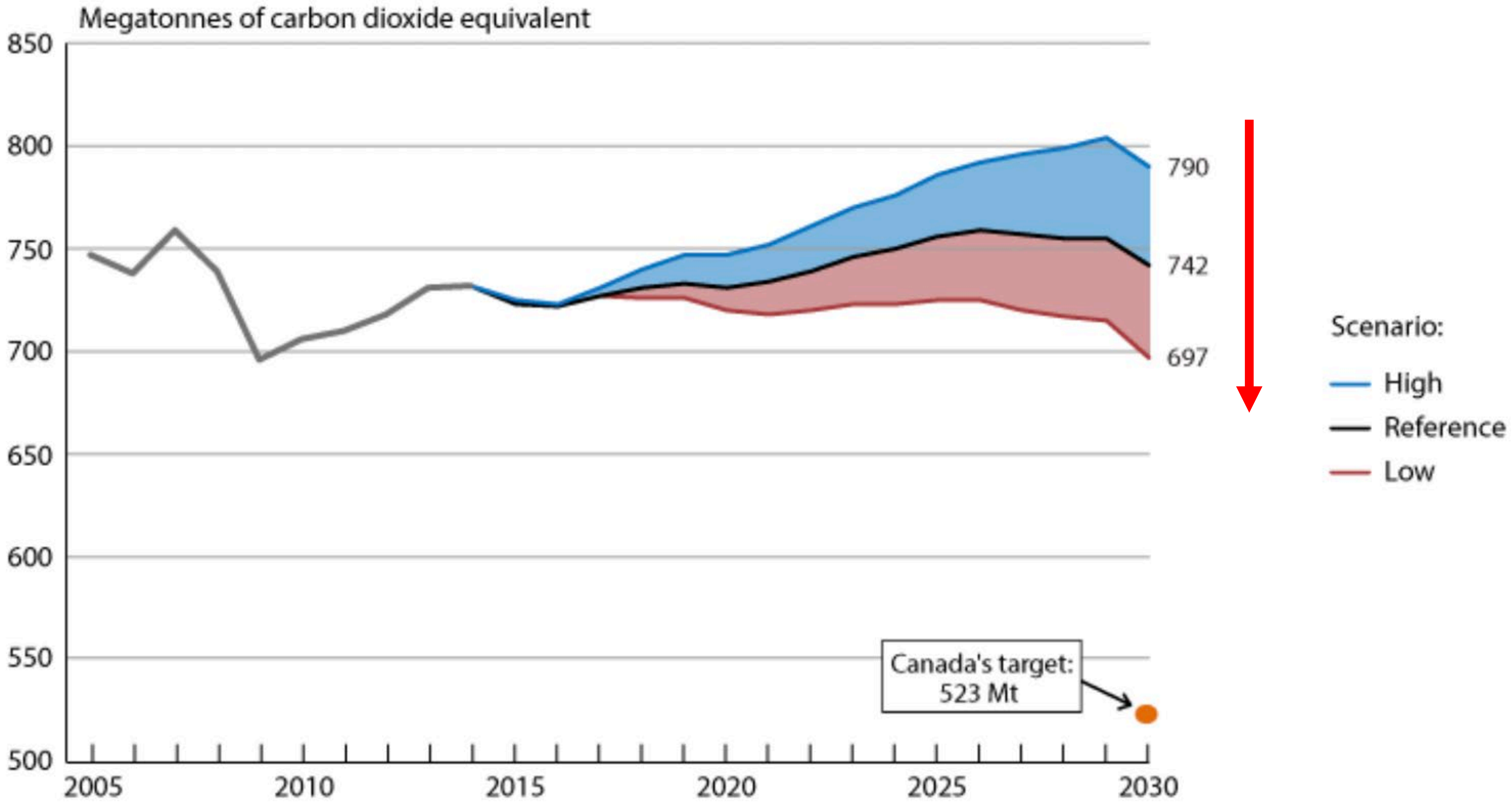
The building sector accounts for about 33% of GHG emissions globally, and about 12% in Canada [1]. However, this excludes the manufacturing, transportation, or waste emissions associated with building materials, which would result in a much higher percentage of total GHG emissions.

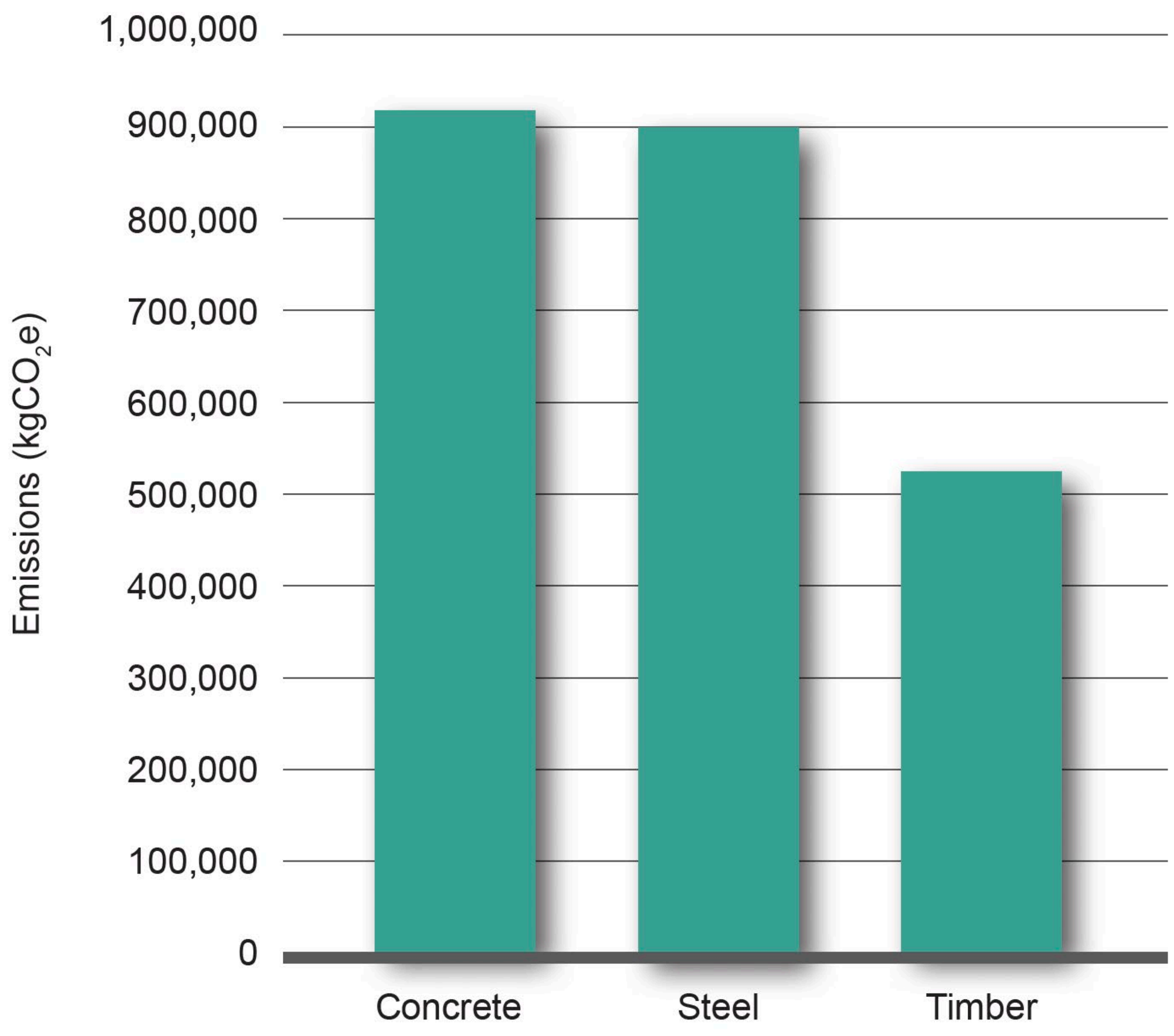
Embodied emissions are the first emissions in a building's lifecycle, and are the majority of a building's emissions for the first 15 to 20 years [3]. Because GHG emission reductions are time critical, the embodied emissions of new buildings becomes a significant factor in reaching climate change targets and commitments set by countries globally.

Figure 1 Canada's Carbon Emissions Projections with Policies and Measures as of November 2016 [1]



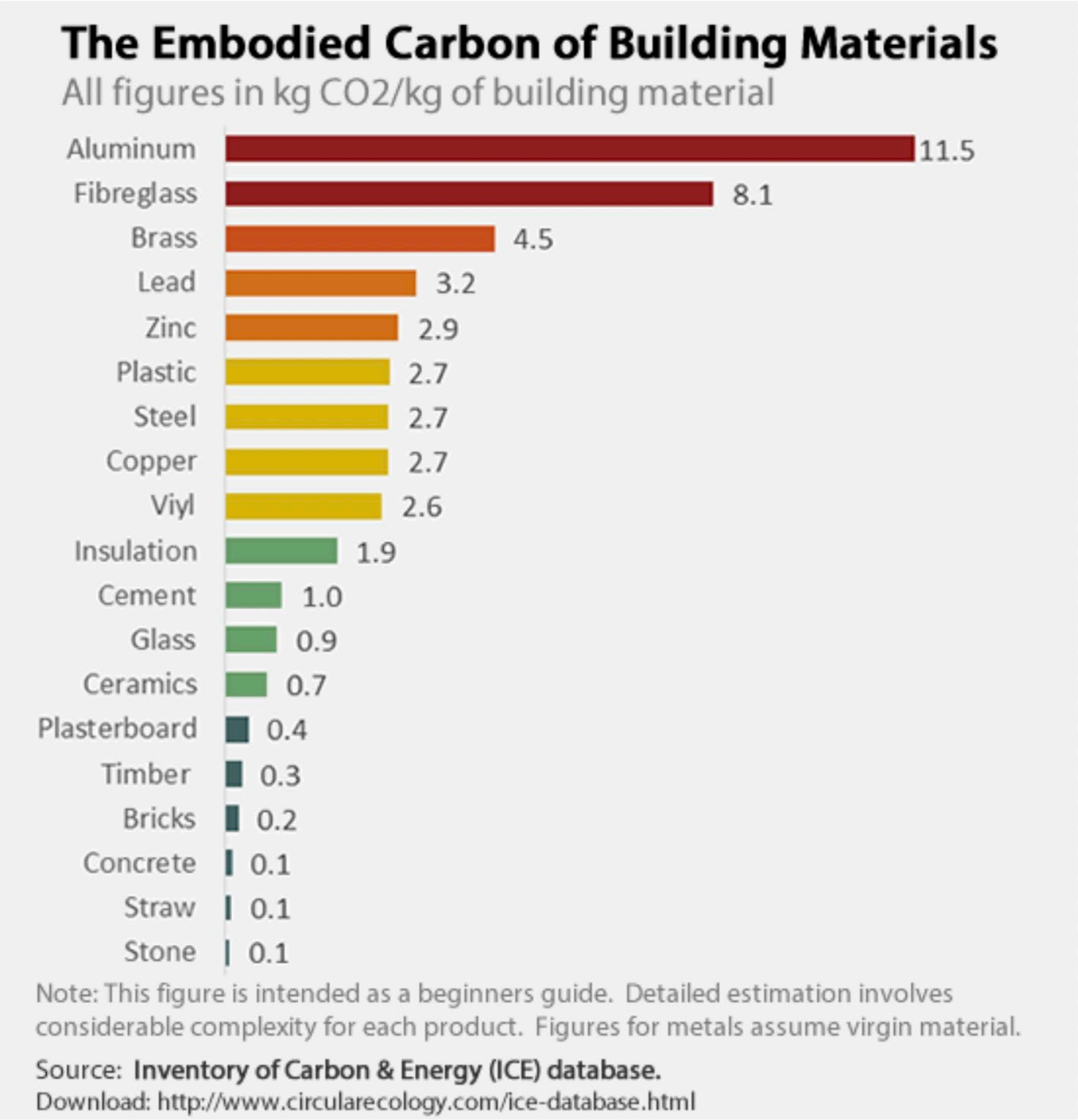
With ambitious government targets that are far outside the historical trends, we must address the issue of embodied carbon in today's new construction

Comparison of Embodied Carbon of Different Structures

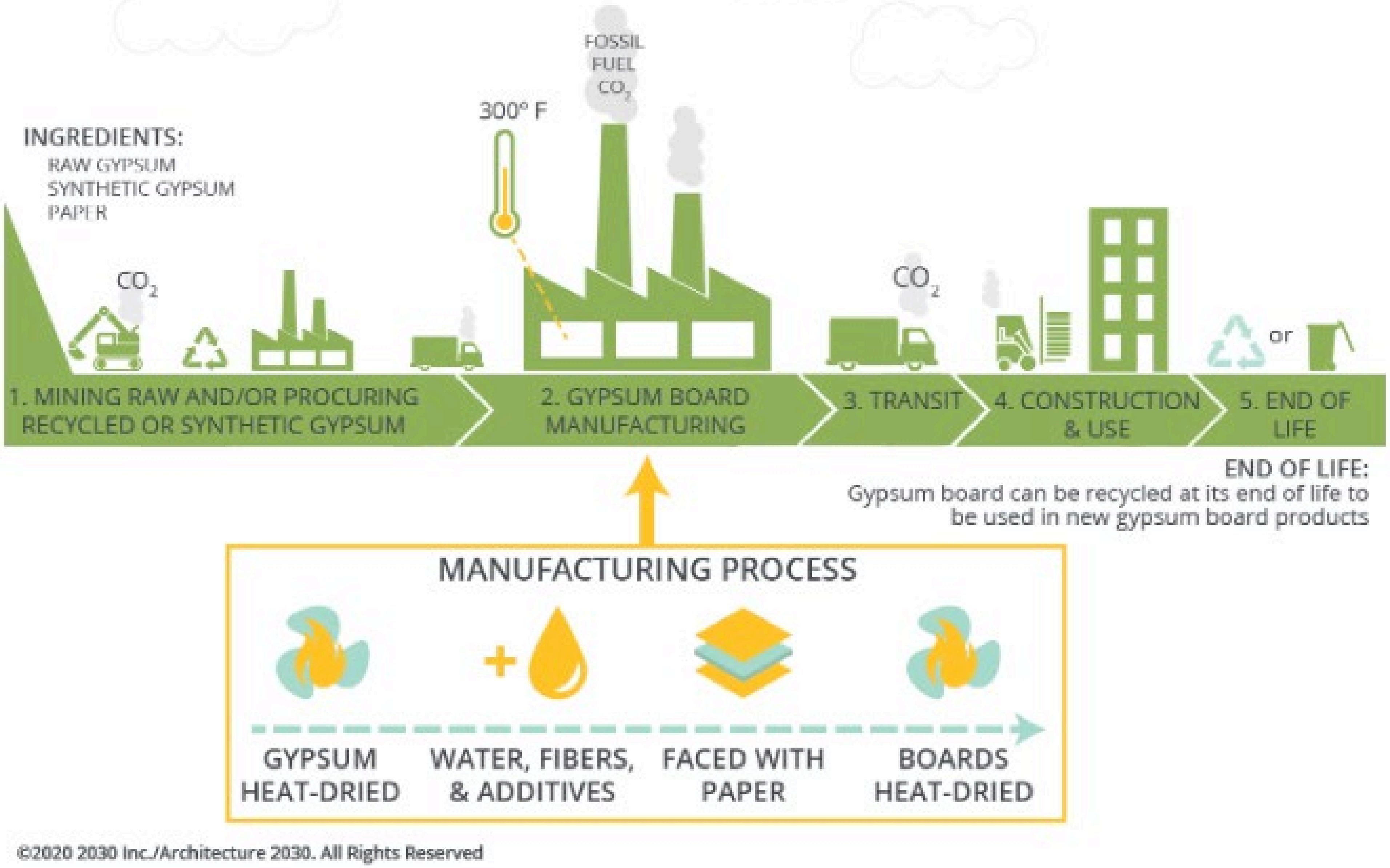


Inventory of Carbon & Energy (ICE) Database

- Material of construction are responsible for the bulk of embodied carbon emissions
- Important to remember figures are on a per kg basis
  - E.g. cement is one of the largest emitters despite it's appearance to rank low on a per kg basis
  - Density and use cases weigh heavily on total impact of construction materials



CARBON IMPACTS OF GYPSUM BOARD



https://www.materialspalette.org/gypsum-board/

CARBON IMPACTS OF GYPSUM BOARD

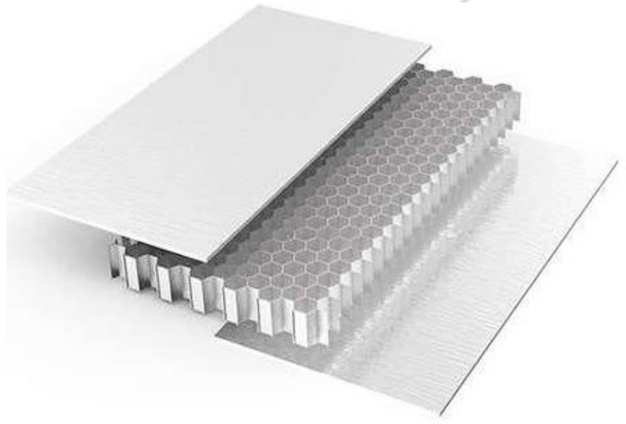
- Every 1,000 board feet of drywall produced requireds about 5,048 MJ of non-renewable primary energy (electricity and natural gas) [4]
- There is a significant amount of waste (estimated at 330,700 tons) per year from new construction alone
  - Over-ordering
  - Incorrect specification
  - Damage and off-cuts
- While it can be recycled finding recycling facilities for gypsum board can be difficult

1 | Gypsum Association; "GA Industry Capacity Shipment Schedule 2019"
2 | Gypsum Association; "2019 Gypsum Association Gypsum Usage"
3 | Greenspec – "Gypsum Plasterboard: Manufacture & Additives"
4 | Environmental Product Declaration – Typical (⅝" Type X) North American Gypsum Boards. Declaration Number FPI/GA/01?2014; Issued May 2015.
5 | Sam Kubba PH.D., LEED AP, in Handbook of Green Building Design and Construction (Second Edition), 2017

BuildingGreen: "Lightweight Drywall: More from Less"
Lushnikova, Nataliya & Dvorkin, Leonid. (2016). Sustainability of gypsum products as a construction material. 10.1016/B-978-0-08-100370-1.00025-1.
Environmental Protection Agency "Emissions Factor Documentation for AP-42 Section 11.16 (formerly 8.14) Gypsum Manufacturing

Let’s do some math

Common construction panels	5/8”Drywall (Gypsum)	¼” Aluminum sheet (Canada made)
Certain surface (SQFT)	1000	1000
Correspondent weight (kg)	1007	322
Equivalent carbon emission (kgCO2e/kg)	0.317	0.920
Emission comparison (kgCO2/1000 SQFT)	320	296



- Although Aluminium production is more emission-intensive, the overall density and construction of panels plays a heavy role in the overall sustainability
- Similarly the use of post-consumer (e.g. recycled) starting material weighs heavily on the emissions generated
- Your mileage may vary, be sure to check with the manufacturer of your materials
    - Location, energy grid composition and individual practices all have a major effect

https://www.canadianarchitect.com/embodied-carbon-key-considerations-for-key-materials/
https://www.gypsum.org/wp-content/uploads/2013/12/Gypsum-2014-FINAL-May-13-.pdf
https://www.netzerocarbonguide.co.uk/guide/designing-and-building/materials-strategy/embodied-carbon-strategies
Aluminum Honeycomb Lightweight and Rigid Wall & Ceiling Panel (primepanels.com)

Recyclability

9%

Plastic Recycling Rate

90%

Aluminum Recycling Rate

75%

Aluminum Produced in last 100 years that is in circulation

5%

Energy Required vs Initial Al Production

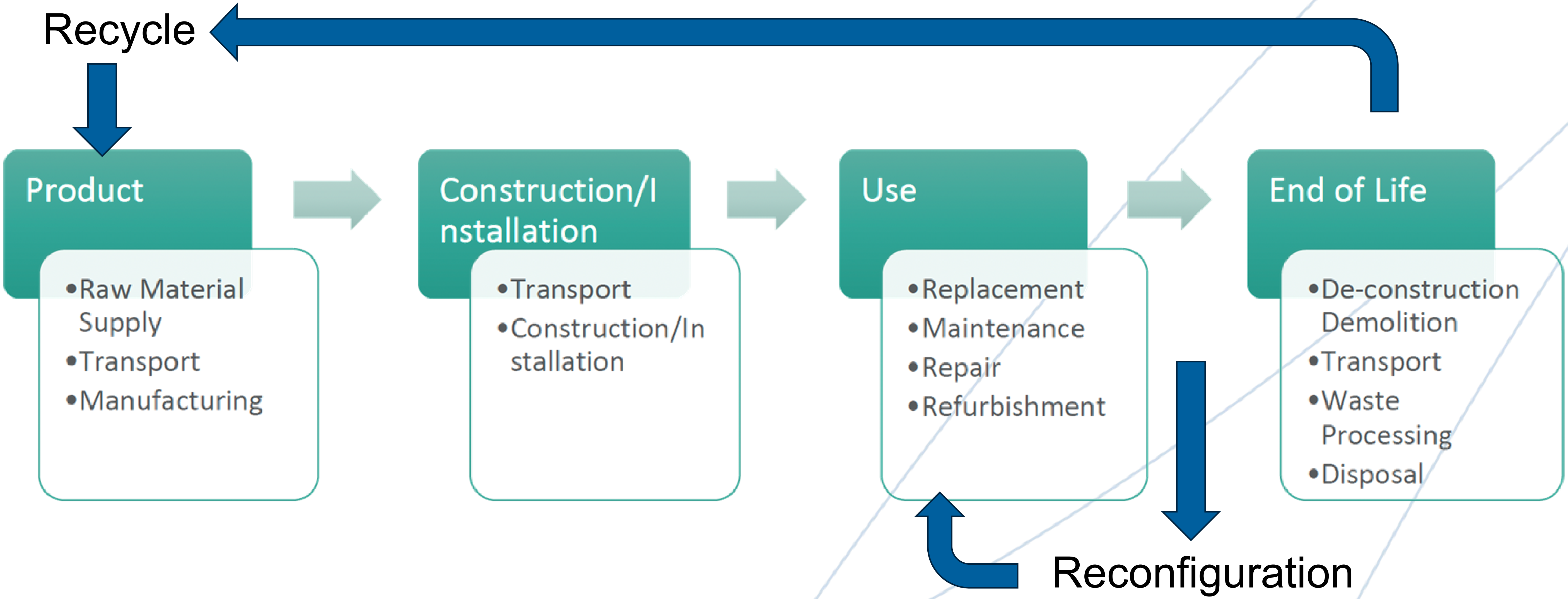
Aluminum vs Steel Framing (factoring in recycled materials)

Assuming a rate of 60% recycling for steel the emission intensity for steel structure will be 0.8 kgCO2e/kg. However, when we take the density ratio into consideration, for the same construction (assuming the same volume of material for studs and tracking) steel will generate 2.17 times more emissions.

Re-Usability

- When using modular or prefab, panelised construction systems, it is important to consider the demountable and reusable nature of some systems
- Panels and ceilings that are re-usable can be treated as a capital asset and avoid the massive carbon footprint of renovations / moves to new or different facilities / the reconfiguration of existing spaces
- With an ever-evolving landscape and rapidly changing capacities and needs of facilities, choosing flexible, re-usable and re-configurable solutions can dramatically reduce the carbon emissions associated with construction and renovation

Benefits of Recycling and Re-Use on Lifecycle



International Trends

- Many European countries have voluntary Environmental Product Declarations (EPDs), which provide life cycle environmental impact data, and are required for manufacturers wishing to make environmental marketing claims [6]

- Germany, France and the United Kingdom offer voluntary building labels and incentives for meeting embodied carbon consumption targets [6]

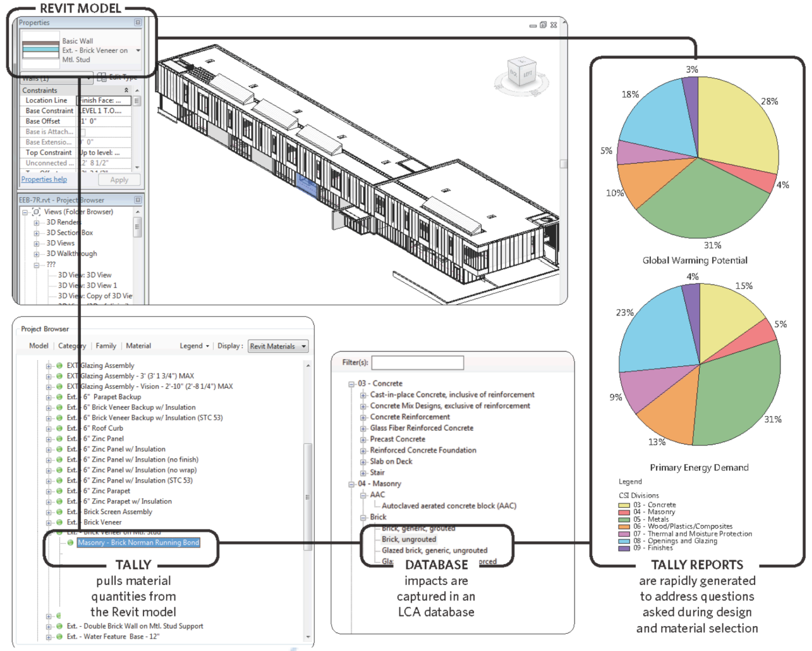
- The Netherlands require embodied carbon reporting for building permit applications for new buildings over 100 m2 [6]

- In Switzerland and Germany, whole building life cycle assessments are required for new government buildings [6]

Software Solutions to Help

- Athena Impact Estimator for Buildings – A software available for free online that relies on input by the user to determine material quantities, or a bill of materials uploaded to the program

- Tally – A plug-in for Autodesk Revit that calculates material quantities based on take-offs from the Revit model.
    - Revit is arguably the most popular software for architects and building design



Thank You!