Global Climate Impact from Hospital Cooling

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COOLING EFFICIENCY PROGRAM

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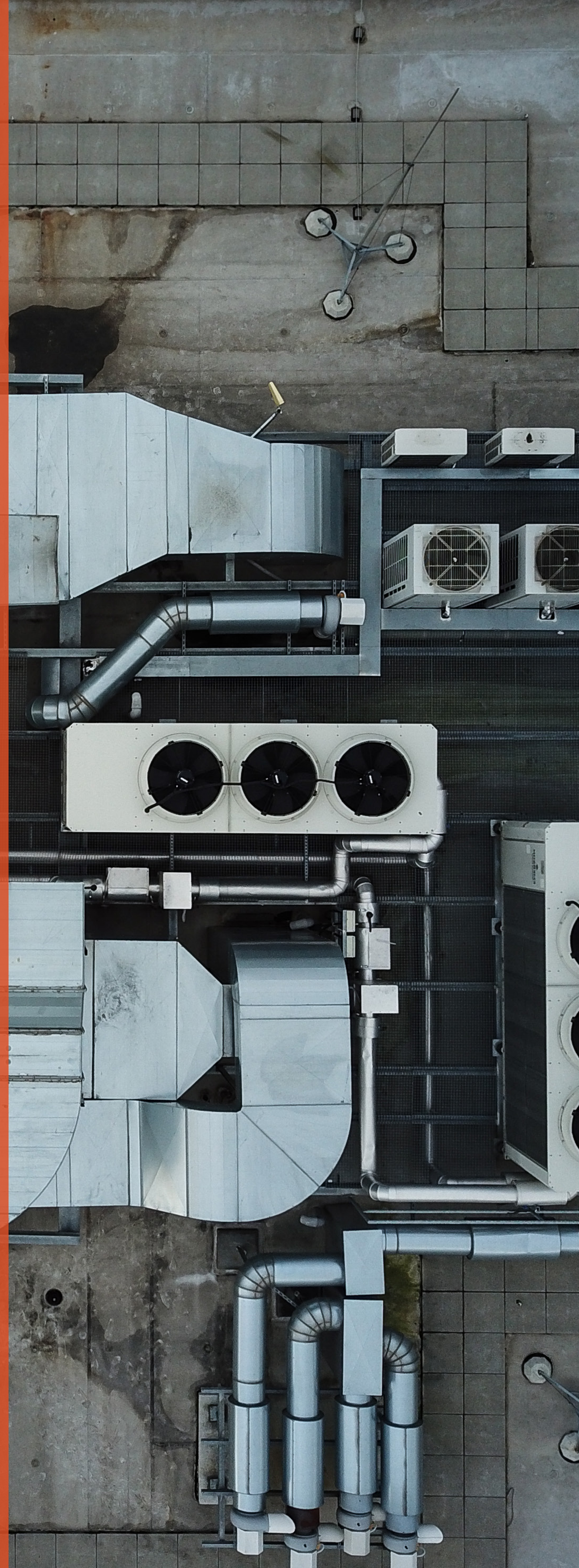

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Kigali Knowledge Brief

Kigali Cooling Efficiency Program (K-CEP) Knowledge Briefs explore efficient, clean cooling topics and provide information to a variety of audiences, including policymakers, foundations, public sector representatives, businesses, and civil society. The briefs are intended to inform decision making about efficient, clean cooling.

Executive Summary

Cooling is crucial for health. Thermal regulation minimizes heat stress and improves mental function and sleep. Refrigeration prevents spoilage of food, medicines, vaccines and blood. Not surprisingly, hospitals have large demands for cooling for patients and for medical products. Given that hospitals' cooling demand requires large amounts of energy consumption, hospitals are also responsible for greenhouse gas emissions, representing a **significant**[1] **percent of healthcare's climate impact.** Until now however, while there have been select country estimates, there have been no global estimates for the climate impacts of hospital cooling; this brief and the underlying approach estimated the collective climate impact of hospital cooling globally.

The climate impact from hospital cooling is significant and rising. Globally, roughly 365 Mt CO_2e (+/- 90 Mt) annually comes from hospital cooling. This is equivalent to the emissions from over 75 million cars on the road or 110 coal power plants[2] for an entire year. With increased attention to providing better and more health care and associated increases in spending (particularly in middle income countries), and absent efforts to improve efficiency and/or decarbonize the power grid, compared to present day, annual hospital cooling emissions could **almost quadruple by 2040 (to ~1,360 Mt CO_2e per year**). *Note that we are not modeling the climate impact of harmful F-gases used in cooling, such that the total emissions and potential benefit could be up to twice what is presented here (see the Methodology box).*

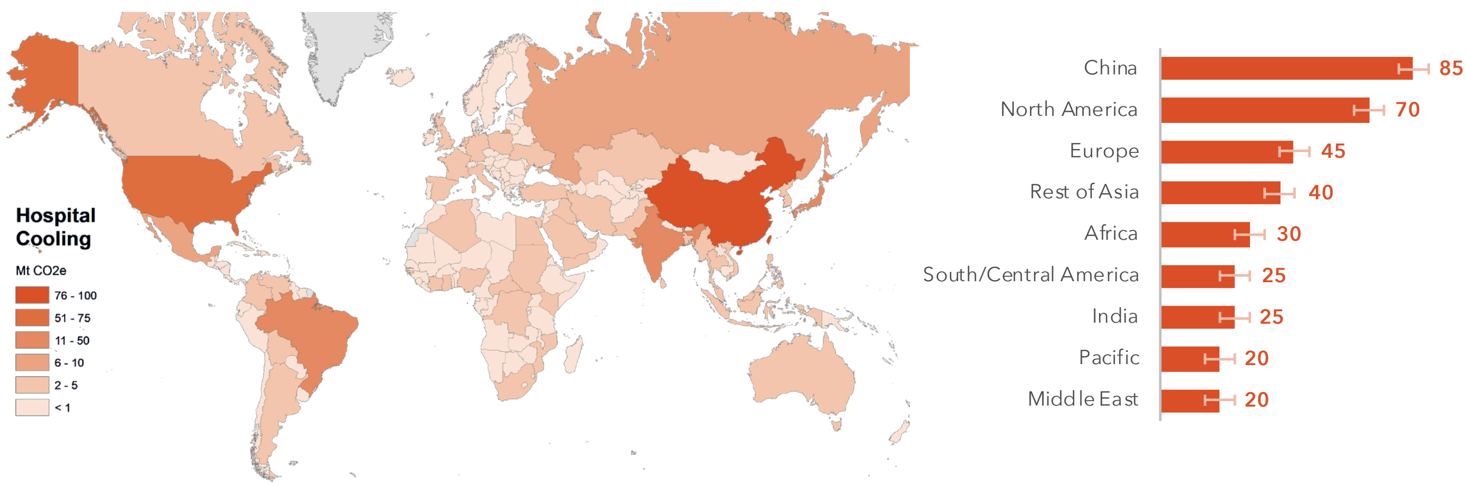
> Hospital cooling globally is currently **365 Mt CO_2e per year** but could quadruple by 2040. That's equivalent to emissions from **75+ million cars** and **110 coal power plants.**

Significantly, most of the energy used for cooling in hospitals is to maintain cool ambient temperatures. In the US, space cooling uses the most energy (70 percent for cooling and another 15 percent for

Figure 1: Hospital Cooling CO_2e by Region

Annual Mt CO_2e, current

Plus/minus bars show ½ standard deviation across scenarios



1 In the US, hospital care emissions are roughly 36 percent of total health care emissions, Environmental Impacts of the U.S. Health Care System and Effects on Public Health, Eckelman et al 2016, doi.org/10.1371/journal.pone.0157014

2 E.g., for coal plants producing ~3.3 TWh annually

related ventilation[3]); refrigeration represents roughly 15 percent of the emissions. Looking globally, as estimated through this analysis, the numbers skew even more to keeping rooms cool (~92 percent), with only eight percent for refrigeration.

Our modeling showed that three countries – **China, the US, and India – represent 45 percent of the total hospital cooling CO_2e emissions.** Japan, Brazil, and Mexico add another ten percent collectively. Sixty percent of the climate impact comes from seven countries. Figure 1 shows the map of the most prominent emitters and a summary by major region.

Solutions are readily available to reduce hospital cooling emissions without compromising patient care; in fact, efficient cooling can reduce the cost of providing healthcare. Solutions include: procurement of high efficiency low global-warming potential (GWP)[4] coolant air conditioners, chillers, and refrigerators; designing passive cooling into new and existing buildings to reduce the cooling load; enhancing ventilation and cooling strategies; taking a systems approach to cooling; improving energy management systems; and expanding onsite and offsite use of renewable power. We provide multiple case examples from China to Sudan including hospitals, universities, and entire health ministries that are embracing efficient and low-GWP cooling methods and improving hospital building designs. **Reducing the energy used for hospital cooling and refrigeration by 30 percent could abate ~110 Mt CO_2e per year currently, equivalent to installing 27,400 wind turbines.**[5] **By 2040, the benefit could be almost quadruple.**

Methodology: What is included?

Methods: This knowledge brief is based on **three methods** used to estimate the hospital cooling emissions from each country globally, including bottom-up and top-down approaches: 1) Hospital-derived, adjusted for cooling-degree days and electricity CO_2e intensity, 2) Total CO_2-derived, taking the percent for healthcare/hospital needs and adjusted by cooling-degree days, and 3) Space cooling for services energy-derived, taking the percent of how many services are for hospitals. Full details are in the Appendix. The difficulty in data collection was the prompt for using multiple methodologies in the hope that several converging lines of evidence would strengthen our confidence in the results.

What is included: The estimates **do include CO_2e** emissions that derive from electricity and other sources (such as natural gas) used to run **air conditioners,**[6] energy used for **cooling ventilation,** and electricity used for **refrigeration** (keeping medicines, food, blood, organs, etc. cool). The estimates are grounded in **current** emissions, but we forecast a **rough estimate for total emissions in 2040** extrapolating from projected increases in health spending and population growth (see Appendix for details).

What is not included: The estimates **do not include the non-CO_2 impact of using high global warming potential (GWP) refrigerants** (such as R-22), an important aspect of the Kigali Agreement. Given that efficiency increases are potentially on par with the benefit of phasing down harmful F-gases used in cooling,[7] the **total emissions and potential benefit could be up to twice** what is presented here.

3 Using data from US Energy Information Administration, 2012 data with actual data on 409 inpatient buildings representing ~9,580 inpatient buildings (hospitals). Known ventilation energy usage was distributed to cooling by the percent of cooling energy versus cooling and heating energy (e.g., ventilation is needed to move around cool and warm air), see the Appendix Method 1. https://www.eia.gov/consumption/commercial/data/2012/index.php?view=microdata

4 Typical hydrofluorocarbons used in air conditioners have high GWPs – with thousands of times more warming potential than CO_2 (20- and 100-year high global warming potentials (GWP) https://www.epa.gov/ghgemissions/understanding-global-warming-potentials, http://unfccc.int/ghg_data/items/3825.php). Low GWP units have values ranging from 1-6 (https://www.epa.gov/sites/production/files/2015-09/documents/epa_hfc_residential_light_commercial_ac.pdf)

5 Representing an average US wind turbine of 2 MW, ~3,950 tons CO_2 abated per turbine https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

6 As described in Method 1, direct (scope 1) emissions from natural gas and other cooling (~18% of space cooling energy) are rolled into indirect energy use (via electricity) and yield scope 2 indirect emissions through power grid intensities

7 Phasing down F-gases for cooling could reduce warming by up to 0.5°C by 2100, www.igsd.org/wp-content/uploads/2017/05/HFC-Primer-19May2017.pdf. Using more efficient cooling technology, such as super-efficient air-conditioners, could avoid up to an additional 0.5°C in the same period – savings from a combination of 30% more efficient ACs in combination with low GWP coolants. Lawrence Berkeley National Laboratory. 2015. Benefits of Leapfrogging to Superefficiency and Low-Global-Warming-Potential Refrigerants in Room Air-Conditioning. eta.lbl.gov/sites/default/files/publications/lbnl-1003671.pdf.

Recommendations

We recommend four actions:

1. **Continue to expand the availability and use of highly efficient and low global-warming potential coolant air conditioners, chillers, and refrigerators,** especially using financing that accounts for operational savings (e.g., considers reduced electricity) and procuring in bulk to reduce the price. This applies to both new and replacement units and can be facilitated by procurement standards adopted by ministries of health, hospitals and multilateral funding agencies. Financing options should look at lifecycle costs and consider reduced electricity costs by running efficient units (e.g., by offering attractive interest rates for efficient units or through pay-as-you-save ideas as Smart Joules uses in India). While all countries have potential to lower hospital-related cooling GHGs, action is particularly needed in the countries contributing most to hospital-related cooling emissions, such as China, the US, India, Japan, Brazil, and Mexico.

2. **Improve hospital building design to incorporate passive cooling and ventilation and improved ventilation and cooling strategies.** This can include using cool roof materials, less glass, increasing shading, orienting buildings to take advantage of wind, increased natural ventilation, zone temperature control, and night setbacks. While some of these measures could be implemented in existing hospitals, they are expected to be most cost-effective when introduced in the planning and design of new hospitals.

3. **Take a systems approach to reduce cooling load and capture waste cold, automating where possible and collecting better data that can inform further improvements.** This can mean using intelligent control systems to help properly manage and optimize the amount of energy used for cooling. Additionally, ensure existing units are serviced and maintained to optimize efficiency.[8]

4. **Expand onsite and offsite use of renewable power** within healthcare (for cooling and other needs). This could include hospital-level district cooling that could also help balance variable renewable power.

In the sections that follow, this Knowledge Brief provides an overview of the methods used to estimate hospital cooling emissions, results by country, a brief look at potential solutions, case examples, potential abatement impact, and a conclusion. An appendix provides further details on the three methods behind the CO_2e estimates, data sources, scenarios, and detailed results.

8 KCEP Knowledge Brief on Optimization, monitoring, and maintenance of cooling technology. http://k-cep.org/wp-content/uploads/2018/03/Optimization-Monitoring-Maintenance-of-Cooling-Technology-v2-subhead....pdf

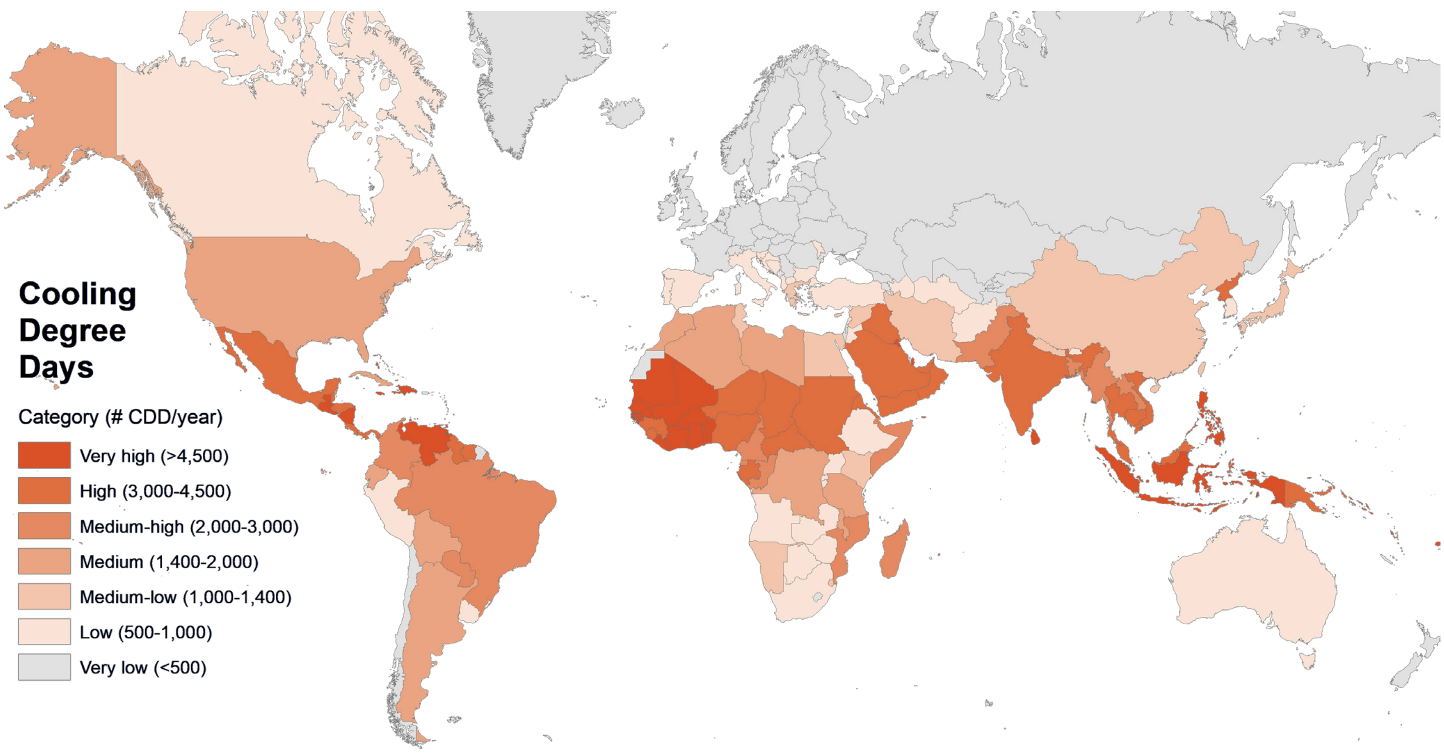
Introduction: Global Climate Impact from Hospital Cooling

Hospitals are open 24 hours a day; have thousands of employees, patients, and visitors occupying the buildings daily; and use sophisticated heating, ventilation, and air conditioning (HVAC) systems to control the temperatures and air flow (e.g., keeping temperatures for operating rooms low and constant). As a result, hospitals consume large amounts of energy.[9] Beyond HVAC needs, many energy intensive activities occur in these buildings: refrigeration, laundry, medical and lab equipment use, sterilization, computer and server use, and food services. In this brief we focus on the CO_2e emissions from hospital cooling, which provides overall temperature regulation (space cooling, operating rooms) and keeps medicines, food, blood, organs, and bodies cool (refrigeration, morgues).

Methodology Overview

Until now, there were no global estimates for the greenhouse gas impacts of hospital cooling. Contributing factors to explain this might include the variable or uneven data availability and limited data from real buildings. Nevertheless, having an estimate of hospital cooling's climate impact is important for reducing carbon pollution and to uncover opportunities for energy and cost savings for hospitals. When creating the methodology, we choose to use three different methods to estimate hospital cooling's climate impact that approach the problem from different directions and see how or if they converged, in the hope that several converging lines of evidence would strengthen our confidence in the

Figure 2: Cooling-Degree-Days (CDD)



9 In the US, large hospitals accounted for less than 1 percent of all commercial buildings and 2 percent of commercial floor space but consumed 4.3 percent of the total delivered energy used by the commercial sector in 2003. Source: Commercial Buildings Energy Consumption Survey (CBECS), Energy Characteristics and Energy Consumed in Large Hospital Buildings in the United States in 2007, https://www.eia.gov/consumption/commercial/reports/2007/large-hospital.php

results. Two of the three methods used, though coming from very different perspectives, yielded similar results. A third came in lower (see below for details). We chose to include the third method for the sake of transparency.

All methods estimated country-level emissions for 193 countries across the globe. These methods were: 1) **Hospital-derived,** adjusted for cooling-degree days, regional temperature norms, and electricity CO_2e intensity (a bottom-up estimate with ranges from 265-395 Mt CO_2e per year by scenario), 2) **Total CO_2-derived,** taking the percent for healthcare/hospital needs and adjusted by cooling-degree days (a top-down estimate with ranges from 325-620 Mt CO_2e per year by scenario), and 3) **Space cooling for services energy-derived,** taking the percent of how many services are for hospitals (estimates range from 40-80 Mt CO_2e per year by scenario and rely heavily on an International Energy Agency (IEA) estimate of space cooling energy use[10]). For each method, we explored variation within the estimates and used a weighted average across scenarios to reflect the confidence behind the approach, method, and underlying data. For a detailed description of the methodology, scenario results, and weightings, see the Appendix.

Summary and Results by Country

In total, hospital cooling contributes roughly **365 Mt CO_2e annually (+/- 90 Mt,** plus/minus ½ standard deviation), **globally**. This includes space cooling, ventilation, and refrigeration and is the equivalent to the emissions from over 75 million cars on the road or over 110 coal power plants for an entire year. Using expected spending increases (by income category), and without efforts to improve efficiency and/or decarbonize power, we estimate that this could **almost quadruple (~1,365 Mt CO_2e per year) by 2040** (reflecting increasing per capita spending, population growth, and enhanced temperature regulations standards, see the Appendix for details).

Figure 3 shows the current results by country for the top 14 countries. China, the US, and India represent 45 percent of the total tons for hospital cooling, and Japan, Brazil, and Mexico add another ten percent collectively. China and India, while at the top of the list with the US, have a lower climate impact on a per hospital basis than the US (50 and 18 percent, respectively) and on a per person basis (36 and 11 percent).

Sixty percent of the climate impact comes from seven countries. By region, **the top countries are:**

- **North America**: United States, Mexico, and Canada
- **Asia:** China, India, Democratic People's Republic of Korea, Indonesia, the Philippines, and Thailand
- **Europe:** Russia and Germany
- **Africa:** Guinea-Bissau, Nigeria, Democratic Republic of the Congo, and South Africa
- **Middle East:** Saudi Arabia, Iran, and Yemen
- **South/Central America:** Brazil and Argentina
- **Pacific:** Japan and Australia

As a reminder, the paucity of data sources makes comparisons between countries inherently uncertain exercises. Additionally, because local standards often dictate temperatures (especially in operating rooms), countries with the best hospitals (e.g., U.S., Europe) are likely on the higher range of the range bar and countries with lower standards or different practices may be on the lower end of the range bar (for example, in India only a small percent of hospitals use round-the-clock air conditioning, some may not have air conditioning, or they may use higher temperature standards to limit energy consumption[11]).

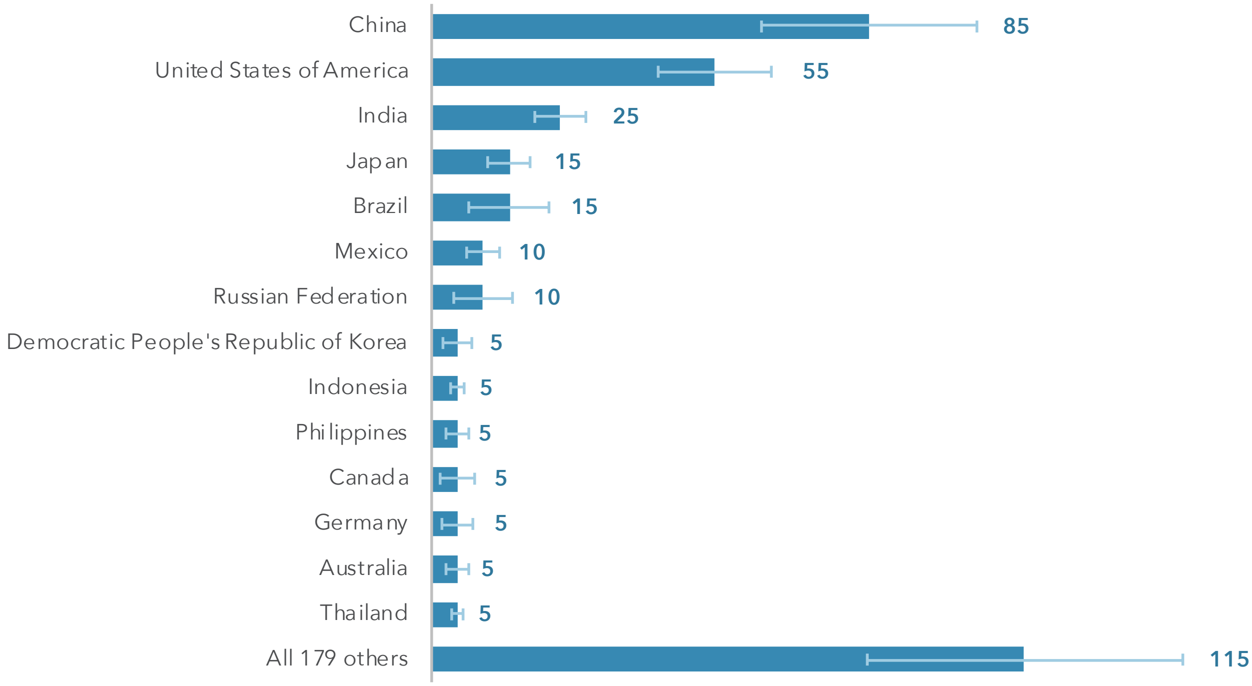
10 Because this is notably lower than estimates from other organizations such as Lawrence Berkeley National Laboratory (https://eta.lbl.gov/sites/default/files/publications/lbnl-1005798.pdf) and CLASP (http://united4efficiency.org/countries/country-assessments/), the third method receives the lowest weighting.

11 Such as 24 C as a default setting. https://www.business-standard.com/article/economy-policy/power-ministry-considers-making-24-degrees-as-default-setting-in-acs-118062200999_1.html

Figure 3: Hospital Cooling CO_2e Emissions by Country

Mt CO_2e, current

Based on weighted average of three methods and varying assumptions within (see the Appendix for details). Plus/minus bars show ½ standard deviation. See Table 2 for details by scenario.



Solutions and Case Examples

Solutions

Solutions are readily available to reduce CO_2e emissions from cooling in hospitals without compromising patient care. In fact, energy efficiency can result in cost savings that can free up budgets for better patient care. Solutions include:

- **Strengthen procurement standards to include higher efficiency and lower-GWP requirements.** Ministries of health, health systems, hospitals and United Nation agencies such as the World Health Organization, should establish procurement policies, product descriptions, and tender specifications requiring high efficiency/low global warming potential coolants in air conditioning and refrigeration equipment.

> Highly-efficient air conditioners only use **half as much energy** compared to traditional ACs
>
> *- Advanced Cooling Market Tracker*

- **Design and retrofit passive cooling into buildings** to reduce the electricity cooling load. Specific ideas are to:
    - **Use cool roof materials** (e.g., reflective roofing)
    - **Design with less exterior glass** (see box at right)
    - **Improve shading** through building overhangs or planted trees
    - **Orient new buildings** to maximize natural ventilation/cooling impacts of wind patterns
    - **Design with thermal mass** that buffer inside temperatures from outside ones
    - **Consider pre-cooling ventilation** air through earth tubes or thermal labyrinth technologies
- **Take a systems approach to cooling** to reduce the cooling load (if allowed by building codes[12]) and capture waste cold. Specific ideas are to:
    - **Increase natural and mixed mode ventilation,** potentially facilitated by operable windows where practical or possible
    - **Employ zone temperature control** and partial air recirculation
    - **Use night or unoccupied setbacks** where the ambient temperatures are higher at night (e.g., if not essential for patients or workers) or when areas are not used (to decrease the cooling load)
    - **Utilize night purging,** where air in the hospital is expelled at night to remove hot air and bring in cooler exterior air
    - **Implement hospital-level district cooling** (which would use underground insulated pipes pumping cold water to multiple hospitals in a district, neighborhood, or city)[13]
    - **Capture waste cold and think 'thermally' in using cold for cooling and storage, such as using ice or snow "thermal batteries" for cooling** (e.g., high density storage of snow) where possible for overall or peak cooling needs. Ice storage saves CO_2 by creating ice during low load times and using the ice for cooling during peak energy load times (which currently use more carbon-intensive supplies)

> In the US, hospitals with **less than 25% exterior glass have only half of average cooling load** as those with 26-75% glass, and those with over 75% glass have a much higher cooling load.
>
> *- US Energy Information Administration (see the Appendix)*

- **Improve energy management systems**
    - **Automate energy management** to optimize the amount of energy used for cooling
    - **Perform regular energy audits** to collect more and better data related that can inform further improvements
    - **Use building energy management systems (EMS)**

12 Some local codes regulate the installation and design of ventilation in healthcare facilities. For instance, local codes may prohibit using natural ventilation in certain healthcare spaces and may require certain minimum air change rates.

13 For more information, see http://www.districtenergyinitiative.org/what-district-energy

- **Upgrade equipment to employ the Internet of Things (IoT)** to facilitate active controls and energy management
- **Use renewable energy onsite and offsite** to power cooling units

Financing options

The particular use of these solutions depends on the economics of the equipment and operating costs, and feasibility constraints such as financing options available. One way that these solutions can be paid for is with financing programs that utilize the cost savings from reduced energy use (particularly for retrofits), for example following the Energy Service Company (ESCO) model approach with energy savings performance contracts (ESPC) where the ESCO pays for units and is paid over time by the purchaser through its lowered costs from energy savings. Procurement of new equipment can be made more affordable by bulk buying (for example aggregating across various hospitals) to bring the price down. Other financing options, such as those available in Turkey[14] or recommended by the Energy Sector Management Assistance Program (ESMAP)[15], can include revolving energy efficiency funds, vendor leasing, regular or development bank loans, credit or risk guarantees, public ESCOs, utility financing, ministry of finance financing, donor funding, or carbon financing.

Case Examples

CHINA – Beijing Huilongguan Hospital, a Global Green and Healthy Hospital

By upgrading air conditioners, installing a ground source heat pump, and improving building energy management, Beijing Huilongguan Hospital saves cooling energy consumption (avoiding ~320,000 MWh per year[16]), reduces its carbon footprint and saves money annually (~USD$36,000 saved per year). In addition, the hospital's improved landscaping provides a better environment for patients and staff and indirectly reduces the hospital's energy consumption by reducing heat-island effects and the usage of air conditioning. More details.

COLOMBIA – Ministry of Public Health, Santiago de Cali, a Global Green and Healthy Hospital

GLOBAL GREEN and HEALTHY HOSPITALS

The Santiago de Cali Ministry of Public Health piloted energy efficiency and renewable energy projects and then expanded their use across their five health networks with nearly 100 health services institutions. Energy efficiency projects included the replacement of older air conditioners with inverter air conditioners that use less energy and use refrigerants with lower Global Warming Potential (GWP), replacement of older lighting with LEDs, and infrastructure improvements that expanded the use of daylight and natural ventilation. These were coupled with the installation of solar panels to produce renewable energy and solar collectors to produce hot water. More details (in Spanish).

14 World Bank/ ESMAP, Europe and Central Asia. Energy Efficiency Financing Option Papers for Turkey https://www.esmap.org/node/57878

15 World Bank/ ESMAP, Financing Municipal Energy Efficiency Projects, https:www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_MGN1-Municipal%20Financing_KS18-14_web.pdf

16 Combined with other measures (including updating lights, heating, and shuttle bus routes), the overall energy consumption was reduced by ~17 percent.

SOUTH KOREA – Younsei University Health System, a Global Green and Healthy Hospital

Younsei University Health System reduced its energy costs by over USD$1.7 million per year by implementing multiple energy management and energy saving technologies. These include: replacing old air conditioning equipment with highly efficient equipment, improving the thermal efficiency of refrigerators, ice storage as part of its cooling system, and installing a building energy management system to monitor and control air conditioning and heating to improve comfort and reduce energy consumption. More details.

SUDAN – Salam Centre for Cardiac Surgery, a Global Green and Healthy Hospital

The Salam Centre for Cardiac Surgery is located in a harsh climate and subject to frequent sand storms of the desert. Yet its cooling emissions are significantly lower than comparable institutions because of multiple initiatives. The hospital reduces mechanical cooling demands through passive technologies, such as thick masonry walls with extensive insulation, deep overhangs, and high-performance windows. To alleviate the significant dust infiltration from dust storms, a thermal labyrinth filters and precools outdoor air, reducing the demand on the solar-powered water heating and chilling equipment. More details.

INDIA - Cool Roof

Source: Natural Resources Defense Council (Cool roof summary, Ahmedabad Resilience Toolkit, Cool Roofs – Protecting Local Communities and Saving Energy).

Shardaben General Hospital in Ahmedabad installed a white china mosaic "cool roof" to reduce internal hospital temperatures. The black tar roof had caused warmer indoor temperatures and spikes in heat-related illnesses. The neonatal ward on the top floor was closest to the black tar roof and experienced oven-like conditions, with newborn infants exposed to temperatures hotter than everywhere else in the hospital.

The hospital moved the neonatal unit to the first floor, and replaced the black tar roof with a reflective white china mosaic cool roof. These actions cooled indoor temperatures and reduced heat-related illness, particularly among newborn infants. Ahmedabad decided to apply this heat mitigation technique. Expansion of cool roofs and other heat mitigation techniques reduces the urban heat island effect, and can alleviate the health impacts of extreme heat while simultaneously saving costs on energy.

UZBEKISTAN – Energy efficient and ammonia refrigerant cooling

In the spring of 2018, Uzbekistan launched demonstration projects that use alternative refrigerants, such as ammonia, that are not Ozone Depleting Substances, using funding from the Global Environmental Facility (GEF) and implementation support from United Nations Development Program (UNDP). The country is also pursuing energy efficient technologies with support from the International Expert on Alternative ODS-free Technologies and Safety Standards (e.g., chillers' detailed technical specifications).

Replacing two outdated chillers and more than 200 domestic air conditioners will phase out 400 kg of R22 (an older, high GWP coolant). The demonstration project will also create better working conditions (temperatures) for 2,639 personnel and more than 51,000 patients annually (26 percent are women and 32 percent children). The demonstration project creates an opportunity to scale throughout the country in public buildings.

US and INDIA - Hospital District Cooling

Sources: Stellar energy, Jea Shands Hospital link 1, Jea Shands link 2, India District Cooling

District cooling can help streamline efficiency, operations, and maintenance of cooling systems by piping chilled water for cooling. Stellar systems can improve efficiency up to 40 percent and save costs by up to 20 percent over the lifetime. Stellar Energy worked with hospitals and California's Office of Statewide Health Planning and Development (OSHPD). To design and make the first OSHPD-approved modular chiller plant, meeting the state's strict seismic requirements.

As another example, Stellar Energy worked with Jea Shands Hospital in Florida. The Jacksonville Electric Authority District Cooling Plant for the Shands Hospital was third in a series of district cooling plants to support the city of Jacksonville's downtown infrastructure investment program. The plant was supported the Shands Jacksonville Medical Center, a 635-bed academic hospital, and included 5 chillers with a chilling system with 2,100 gallons per minute tower capacity.

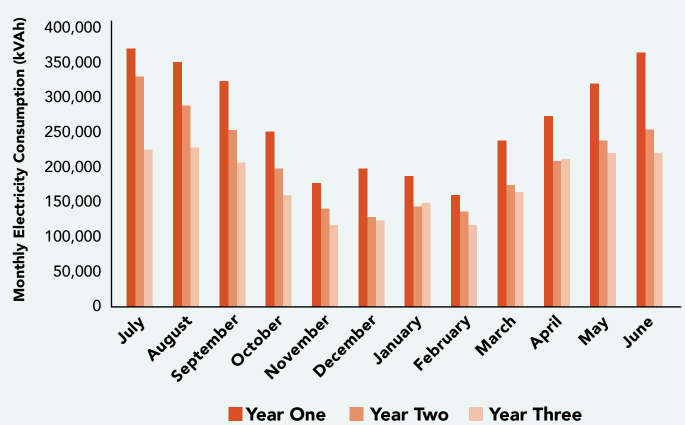
India has a District Energy in Cities Initiative, including work in Thane (within the Mumbai metropolitan region), with aims to also work in cities such as Rajkot and Pune. In southern Indian cities, up to 40 percent of electricity can be for cooling. District cooling is estimated to have the potential to reduce energy demands for cooling by up to 50 percent. The Initiative is partnering with Danfoss for implementation.

INDIA – Smart Joules

Smart Joules aims to improve efficiency in buildings, including integrating efficient air conditioners with artificial intelligence. They have helped 15 hospitals in India with automation by using JoulePAYS, which is an agreement where the organization 'Pays-As-You-Save', has guaranteed energy savings, does not need to invest, provides state of the art energy management technology, and Smart Joules gets a fixed percent of the savings.

As examples, they reduced energy consumption in Sant Parmanand Hospital by 27 percent, St. Stephen's Hospital by 22 percent (see chart), and CMC Ludhiana Hospital by 21 percent. Source link

Reduction in Energy Consumption with JoulePAYS (kVAh) Sant Parmanand Hospital (27%)

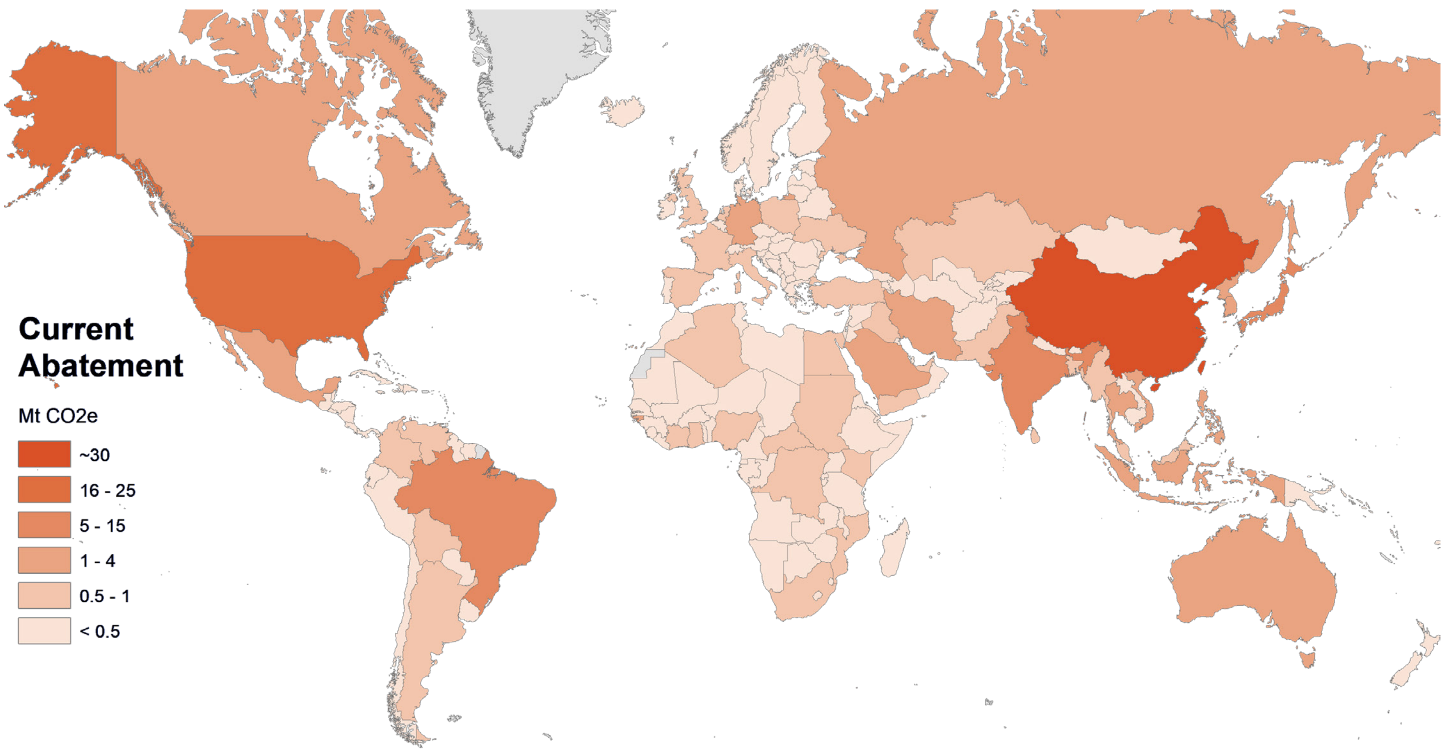


Potential Abatement Impact

Hospitals around the world provide essential services. But cooling in hospitals, for temperature regulation and keeping medicines, food, blood, organs, and bodies cool, has a significant climate impact. Positively, **reducing the energy used for, or climate impact of, hospital cooling and refrigeration by 30 percent**[17] **could abate ~110 Mt CO_2e annually currently,** equivalent to the annual mitigation abatement from installing 27,400 wind turbines. Figure 4 shows how this varies across the world. As an applied example, if a district with 100 hospitals in a moderately warm climate (assuming average CDD across all countries) were to improve efficiency of cooling units by 30 percent, they would abate ~90 kt CO_2e each year and save roughly 240 kWh annually currently.

Figure 4: Current Annual Abatement Potential ~110 Mt CO_2e

Assuming a 30 percent increase in efficiency of cooling. The estimates are low because of excluding the non-CO_2 impact of using high-global warming potential refrigerants



Currently, the number of hospitals per capita are not equal worldwide (see Figure 6). Looking forward, populations and economic well-being are increasing, more attention will be paid to healthcare, spending on healthcare is expected to almost triple by 2040 (reflecting improving economies and global attention to meeting the Sustainable Development Goal of universal health coverage), global population is expected to increase by 25 percent,[18] temperature standards may expand in warm geographies, and more hospitals will be built to deliver critical services.

17 As noted earlier, highly-efficient air conditioners only use half as much energy compared to traditional ACs. We therefore used 30 percent reduction to be moderately, but not overly ambitious

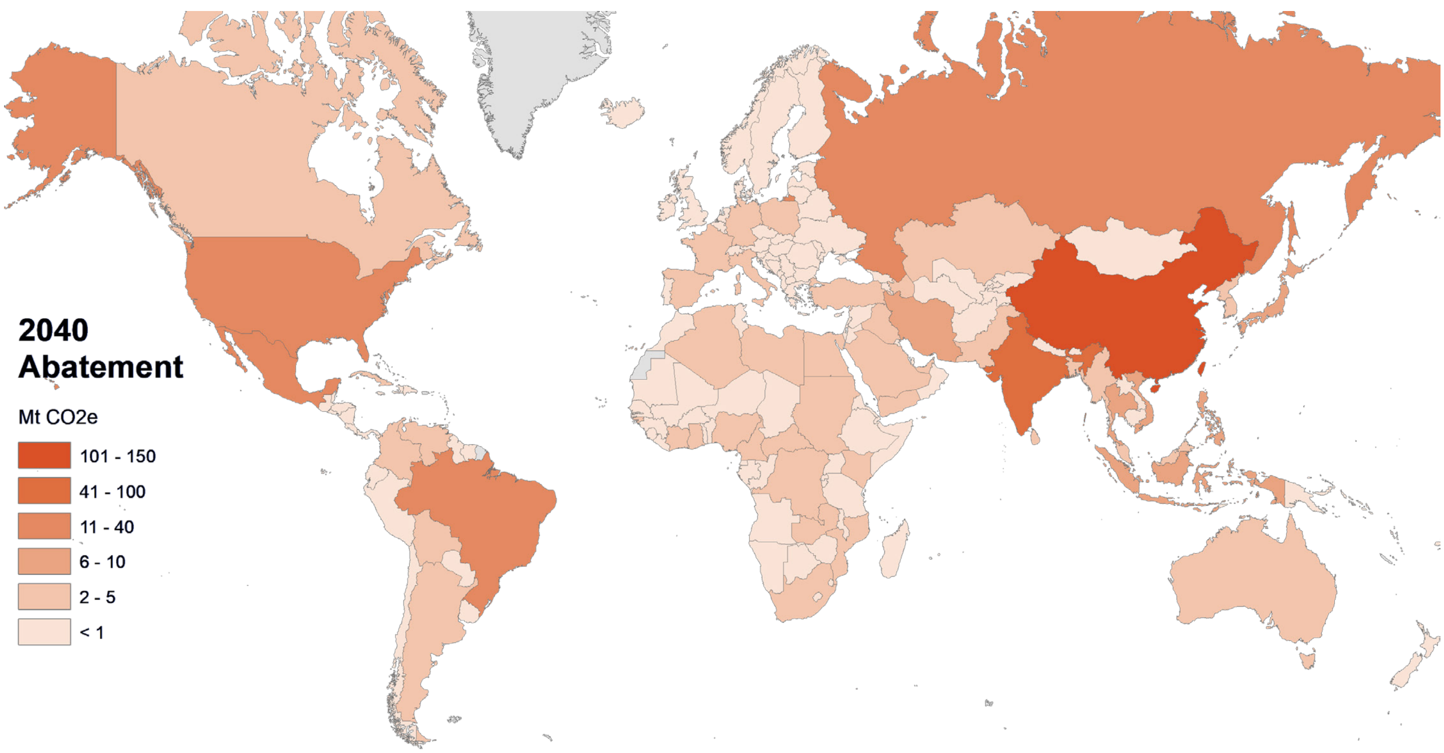
18 United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, medium variant.

Additionally, hospital cooling is neither equally distributed (Figure 1) nor focused in areas where the temperature regulation needs are greatest (shown through cooling degree days in Figure 2). In the future, higher ambient temperatures from climate change are expected and more hospitals will require greater cooling. For example, additional electricity from new in-room ACs purchased between 2010 and 2020 is projected to grow to more than 600 billion kWh globally by 2020 (across all uses).[19]

As a result, hospital cooling needs will grow significantly in the future. As shown by some of the case studies and potential solutions presented in this report, this can and should be done in a climate-friendly way with highly-efficient, low global-warming-pollutant air conditioners and refrigerators. As a result, at minimum **reducing the global hospital cooling and refrigeration need by 30 percent could abate ~410 Mt CO_2e per year in 2040** (Figure 5), equivalent to installing almost over 100,000 wind turbines. Finally, because increases in efficiency are potentially on-par with the benefit of phasing down harmful F-gases used in cooling, the total emissions and potential benefit might be up to twice what is presented here.

Figure 5: 2040 Abatement Potential ~410 Mt CO_2e

Assuming a 30 percent increase in efficiency of cooling. The estimates are likely low because of excluding 1) The non-CO_2 impact of using high-global warming potential refrigerants and 2) Additional expected focus in hospital cooling services on areas with high unmet demands (such as in Africa).



19 IPEEC annual report, 2017, Supporting energy efficiency progress in major economies, https://ipeec.org/upload/publication_related_language/pdf/671.pdf

Conclusion

Hospital cooling is crucial and provides overall temperature regulation (space cooling, operating rooms) and keeps medicines, food, blood, organs, and bodies cool (refrigeration, morgue). However, the related climate impact is significant, rising, and highest currently in China, the United States, and India.

Given the significant climate impact of emissions from cooling in hospitals, implementing solutions to reduce hospital cooling emissions can help with the globally agreed goal of limiting temperature rise to well below 2 degrees. New buildings and new units are essential, but as the lifetime of hospitals exceeds that of units, replacements and retrofits also have potential.

Positively, solutions exist to reduce this load. By pursuing a mixture of efforts focused on improving efficiencies, expanding the use of low-GWP refrigerants in air conditioners and refrigerators, and decreasing the energy and climate impact of cooling, approximately ~110 Mt CO_2e annually could be abated, equivalent to installing 27,400 wind turbines, with almost quadruple the benefit (compared to today) in 2040.

Appendix: Methodology, Sources, Scenarios and Detailed Results

Three methods were used for the estimate: 1) Hospital-derived, adjusted for cooling-degree days and electricity CO_2e intensity, 2) Total CO_2-derived, reduced for healthcare/hospital needs and adjusted by cooling-degree days, and 3) Space cooling for services energy-derived, accounting for how many services are for hospitals. Below are details behind each method (an overview of the approach is followed by detailed data sources), scenarios, and detailed results.

Method 1: Hospital-Derived

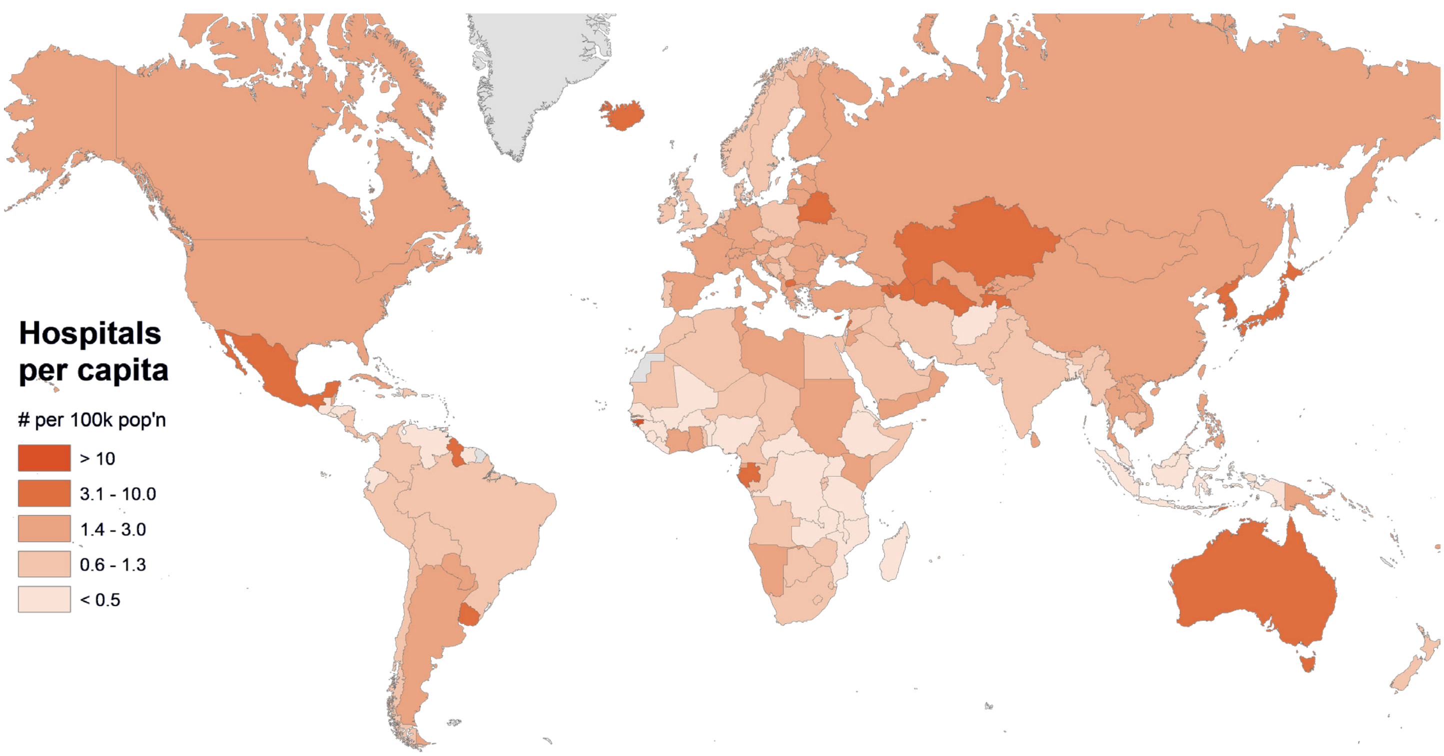
The first method is a bottom-up derived estimate. Underlying data generally was at the country level. The estimates for hospital cooling GHG emission ranged across three scenarios (see below for more details) from 265-395 Mt CO_2e per year (a weighted average of ~320). Below is an overview and key assumptions for this method.

Overview: The first method is primarily driven by the number of hospitals and country-specific cooling needs (driven by energy needs derived from cooling degree days, but also based on country norms), and electricity intensity.

- **Hospitals,** defined as provincial hospitals, specialized hospitals, and district/rural hospitals, but excluding health posts and health centers. Number of hospitals were derived from 1) Country-specific hospitals/population*population (132 countries), 2) Country-specific hospital beds/population*population (48 countries), 3) Region averages of hospitals/population*population (10 countries), and 4) Over-rides of known number of hospitals for four countries (China, India, the US, and Australia). The summary hospitals per person are in Figure 6.

Figure 6: Hospitals per person

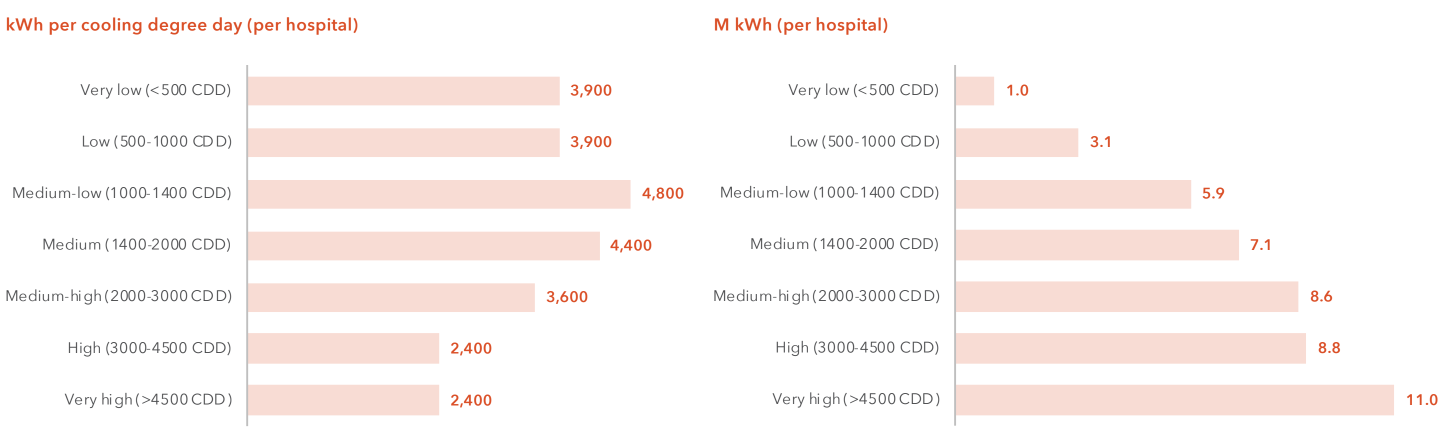
Number of hospitals per 100,000 people. Hospitals included are provincial hospitals, specialized hospitals, and district/rural hospitals. Health posts and health centers are not included.



- **Underlying hospital (inpatient buildings) cooling/ventilation/ refrigeration energy represented all as indirect sources of emissions** (emissions coming from the generation of equivalent electricity to provide that energy).
    - **Ventilation:** The known ventilation energy usage was distributed to cooling by the percent of cooling energy versus cooling and heating energy (e.g., ventilation is needed to move around cool and warm air). In the US, cooling ventilation energy was on average 28 percent of the total ventilation energy, but the percent ranged from ~10 percent for low Cooling Degree Day (CDD) hospitals to ~75 percent for the very high CDD hospitals.
    - **Cooling distribution:** The underlying cooling/ ventilation energy needs for US hospitals used 68 percent electricity (indirect), 14 percent natural gas cooling (direct), 3 percent district heat cooling (direct), and 0.25 percent fuel oil cooling (direct), plus 15 percent for ventilation.
    - **Refrigeration:** On top of this, there is electricity used for refrigeration (16 percent of the total for cooling/ventilation/refrigeration). Looking across the US hospitals, the refrigeration needs per hospital area was relatively constant (~70.4 MW per square meter); when looking at the average size hospital in the US (~23 thousand square meters), this translates into approximately 450 million Wh per hospital – this assumption was applied as a baseline for every hospital (and not adjusted for cooling degree days).
    - The energy used or all of these categories (BTUs) was converted into equivalent kWh, thereby representing all as indirect emissions (e.g., this assumes that natural gas emissions are similar to the country's current grid CO_2e intensity). Note that the impact of high warming refrigerants (such as R-22, a hydrochlorofluorocarbon) was not taken into account.
- A detailed data source on inpatient hospital buildings in the US was used to determine the **per hospital electricity needs by cooling-degree-days** (see Figure 7). Two approaches looked at kWh per cooling degree day (per hospital) and million kWh per hospital by seven groups of cooling degree days (from very low < 500 CDD to very high >4500 CDD). See Figure 7.
- **Space cooling needs were adjusted to different temperature norms** (a variable assumption). Across the world, there is a diversity in hospital buildings codes (for example some use more natural ventilation), interior temperature comfort expectations, and building typology variation. This assumption accounts for this variation with one variable – assuming warming temperatures as the baseline for calculating needed cooling. Comparing adjusted cooling degree days to the original CDDs then lowered the cooling needs relative to the US benchmark (e.g., the top 5 countries were 70-95 percent of the US energy needs).

Figure 7: Electricity needs by cooling-degree-days (CDD)

LEFT: kWh per cooling degree day (per hospital). RIGHT: M kWh per hospital
Based on detailed set of data on 409 inpatient hospitals in the US



- ***Hospital cooling Mt CO_2e per year* = Electricity intensity** (g CO_2e/kWh, varies by country)* **CDD-adjusted kWh/hospital * Hospitals * Cooling adjustment + Refrigeration need/hospital * Hospitals,** where CDD-adjusted kWh/hospital = average of CDD*kWh/hospital/CDD – by groups of CDD and kWh/hospital by groups of CDD (see Figure 7).

Scenario key assumptions: We varied the temperature norm by assuming a **0-, 5-, or 10-degree Celsius difference in cooling** needed (e.g., assuming 23˚C or 28˚C are the standard instead of 18˚C). Note that per the ASHRAE[20] standard 170, operating rooms should be kept around 18.9-23.9˚C (66-75F) and are often kept cooler.[21] Hospital guidelines in India's intensive care units range from 22-25˚C inside, up to 28˚C round the clock (see below). Increasing the reference temperature lowered the respective CDD for a specific country, which reduced the cooling need (see Figure 7). To represent base loads of a hospital due to likely hospital temperature standards, a maximum discount of **50 percent** was applied.

Method 1: Data Sources

- **Total hospitals for select countries:** India (National Health Profile 2018, 23,582 hospitals, Chapter 6, Table 6.2.2), China, (2016 data, 29,140 hospitals),[22] and Australia (972 hospitals, 2012)
- In India, Public Health Standards Guidelines for District Hospitals (from 2012) only include temperature regulation requirements for Intensive Care Units and Occupational Therapy (OT) and not in spaces outside of these areas. For example, district hospitals: "Temperature inside Special Newborn Care Unit (SNCU), is to be maintained at 28 C +/- 2 C (78-86F) round the clock preferably by thermostatic Control plus the temperature inside SNCU should be set at the level of comfort (22˚ – 25˚C) (71.6-77F)."
    - We used these temperature standards to inform the scenarios (using 23C and 28C as standards).
    - We also assumed that the cooling needs only apply to a part of the hospitals in India. Based on 2009 data in the US, ICU bed were ~8% of total beds. Accounting for additional space for OT, we assumed ICUs and OTs take up roughly **15% of the space** in India. For future projections (to **2040), we assumed that this might double (where 30%** of the space in hospitals have temperature regulations).
- **Detailed US Hospital Data:** US Energy Information Administration, 2012 data for 409 inpatient buildings, with weights represents ~9,580 inpatient buildings (hospitals)
- **Hospitals per Population:** World Health Organization (WHO, using district/rural, provincial, and specialized hospitals) and World Bank (WB) World Development Indicators (using the most recent data available, which varied from 2001 to 2015 based on the country).
- **Hospital Beds per Population:** WHO (most recent data, up to 2015)
- **Population:** WHO (2015 data)
- **Cooling Degree Days:** Center for Global Development, Energy+ Country Performance Ratings 2001–2010 (data, paper), 2011 data
- **Electricity CO_2e Intensity (g CO_2/kWh):** Where country-level data was unavailable (from IEA or IGES), regional averages from IGES and then from IEA ETP were used
    - For major regions (e.g., OECD), data from IEA Energy Technology Pathways (2017 report using 2015 data), using data for 24 individual countries
    - For 76 developing countries, data from Institute for Global Environmental Strategies (IGES) (data)

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20 American Society of Heating, Refrigerating and Air-Conditioning Engineers

21 Page 11 https://www.techstreet.com/ashrae/products/preview/1999079

22 Additional references for China hospitals (2015, 27,587 hospitals, China Statistical Yearbook 2016, 22-8) and (2016, 28,584 hospitals, link)

Method 2: Total CO_2-Derived with Healthcare/Hospital Needs and Cooling-Degree Days

The second method is a top-down estimate, relying more on input assumptions. Underlying data generally was at the country level. The results were broadly similar to Method 1. The estimates for hospital cooling GHG emission ranged across four scenarios (see below for more details) from 325-620 Mt CO_2e per year (a weighted average of ~505). Below is an overview and key assumptions for this method.

Overview: This method starts with the total GHG emissions of a country, estimates healthcare emissions (using benchmarks that vary from 3 percent to ~13 percent based on studies and the income group of the country), estimates hospitals as a percent of healthcare (using a US study as a main reference but offering scenarios/assumptions), gets to hospital cooling emissions (using a US study as a main reference but offering scenarios/assumptions), and then adjusts for cooling-degree-days.

- **Hospital cooling Mt CO_2e per year = Total CO_2e** (Mt CO_2e) * **Healthcare percent** (varying by income group and low/high scenario values) * **Hospital percent** (low and high scenario values) * **Cooling within hospitals percent** (low and high scenario values) * **Cooling degree-day adjustment** (optional, scenario-driven)
- Cooling degree-day adjustment = CDD country / CDD US baseline, with a minimum and maximum applied

Table 1: Method 2 Scenario Key Assumptions

Type	Income Group	Low Scenario	High Scenario	Notes
Healthcare Emission vs. Total Emissions	Low	3%	4%	Range 3-5 (Climate-Smart Healthcare)
	Lower Middle	4%	5%	
	Upper Middle	6%	8%	Range 5-15 (Climate-Smart Healthcare)
	High (UK)	4.5%	4.5%	4.5 in the UK (see data source)
	High (US)	10%	10%	10 in the US (see data source)
	High (Non US/UK)	7%	13%	Range 5-15 (Climate-Smart Healthcare)
Percent Healthcare Attributable to Hospitals	-	29%	36%	29% UK reference, 36% US reference
Percent for Cooling & Refrigeration in Hospitals	-	35%		~35% US reference (23% cooling +6% refrigeration+~5% ventilation). Australia reference: 43% of electricity for all buildings is used for HVAC (assume ⅔ for AC), another 20% is for total equipment (assume ⅓ for refrigeration)
Max Percent Cooling & Refrigeration in Hospitals	-	55%		Estimate. Limits adjustment by CDD to this maximum.
Min Percent Cooling & Refrigeration in Hospitals	-	35%		Represents base refrigeration and ventilation loads. Limits adjustment by CDD to this minimum.

Method 2: Data Sources

- **Total CO_2e Emissions by Country:** World Bank World Development Indicators (link), most recent year (many 2012)
- **US Health Care Emissions:** Environmental Impacts of the US Health Care System and Effects on Public Health, Eckelman et al 2016 (link), which includes an estimate of hospital care emissions (238 Mt CO_2e in 2013), all healthcare emissions (655 Mt CO_2e, or ~10% of all US GHG emissions), and all US emissions (6,673 Mt CO_2e emissions).
- **Healthcare Emissions vs All Emissions:** Climate-Smart Healthcare: Low-Carbon and Resilience Strategies for the Health Sector, World Bank IBRD 2017 (link), providing an overview of the range of healthcare emissions by broad income group (developing countries range from 3-5 percent of all emissions, developed range from 5-15 percent).
- **Healthcare Emissions in the UK:** (link) Building energy was 18% and commissioned health and care services from outside system were 11% of a total 26.6 Mt CO_2e in 2015 (which was ~4.5% of total emissions in the UK).
- **Building and Hospital Energy Use in Australia:** (link) 43% of electricity for all buildings is used for heating, ventilation, and air conditioning (HVAC), another 20% is for total equipment, and 10% for other electrical process. Assuming ⅔ of the HVAC is for AC and ⅓ of total equipment is for refrigeration leads to the high-scenario assumption of 35% cooling/refrigeration within hospitals.
- **Income Categories:** World Bank (link), 2017 data
- For the source/details on Cooling Degree Days, see Method 1

Method 3: Space Cooling for Services Energy-Derived with Hospital Services

The final and third method relies heavily on an IEA estimate of space cooling, which appears to be quite low (when comparing to the other methods). Hospitals are more energy intensive (per square meter) than other buildings generally, which may be a contributing factor to the low estimate from IEA. The summary estimates for hospital cooling GHG emission ranged across two scenarios (see below for more details) from 40-80 Mt CO_2e per year (a weighted average of ~70). Below is an overview and key assumptions for this method.

Overview: IEA's Energy Technology Perspectives buildings data provides an estimate for space cooling GHG emissions (Mt CO_2) for all services for major countries and regions (United States, China, India, Republic of Korea, Japan, Mexico, Australia, Russia, 16 other countries, and groupings such as ASEAN, OECD, or non-OECD). This method takes this as a major input and then discounts to pull out hospitals within all services. However, the starting point for all space cooling services is only 510 Mt CO_2e, hence the hospital cooling component is significantly lower. Because this is notably lower than estimates from other organizations such as Lawrence Berkeley National Laboratory and CLASP, the third method receives the lowest weighting.

- **Hospital cooling Mt CO_2e per year = Space cooling for services CO_2e** (Mt CO_2e) * (1+ **Refrigeration and ventilation percent vs. space cooling) * Hospitals vs total services percent**
- Underlying data was at the country level for 24 countries and was extrapolated to other countries (in OECD and non-OECD blocks) using total emissions by country.

Scenario Key Assumptions: The main crucial assumption is the percent of hospitals vs total services. Scenarios look at a baseline of 6% (based on the US inpatient energy vs. all commercial buildings energy) and a doubling of this (12%). An additional assumption adds refrigeration and ventilation needs at 35% above space cooling needs (driven by the US detailed hospital data).

Method 3: Data Sources

- **Space Cooling GHG for Services and Electricity Intensity:** IEA's Energy Technology Perspectives buildings data provides an estimate for space cooling GHG emissions (Mt CO_2)
- See Method 1 for detailed US hospital data for references of cooling within hospitals, refrigeration vs cooling, and the Cooling Degree Day source

Growth to 2040

Healthcare spending growth to 2040: Institute for Health Metrics Evaluation, Financing Global Health, 2016, issuu.com/ihme/docs/ihme_fgh2016_technical-report. Applied percentage growth in per capita spending by income group (low 160% 2040 vs current, lower middle 320%, upper middle 430%, and high 180%) to each country's current estimate to yield rough 2040 estimate.

Population growth to 2040. United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, assuming the medium fertility variant.

Scenarios

Nine scenarios across the three methods were used. A weighted average across nine scenarios within the three methods yield the summary estimate of global hospital cooling emissions. As previewed earlier, we had different confidence in the various methods and scenarios, with the highest confidence in the bottom up method (#1), then in the CO_2-based top-down method (#2), and the lowest confidence in method 3. As a result, we weighed Method 1 heavily (50% overall), then Method 2 (40%), and put a small weight on Method 3 (10%).

Below is an overview of their respective weightings and summary description on the theory behind the weights.

1. **Method 1 (50% weight total, hospital-derived, with cooling-degree days and electricity intensity)**. This method is weighed the most heavily because of its bottom-up nature.

    a. **Hospitals, Cooling degree days adjust based on 18˚C temp (15% weight).** This scenario reflects the baseline bottom-up estimate if hospitals and countries around the world had similar cooling preferences as in the US (using 18˚C as when cooling kicks on). This baseline adjusts for the differences in ambient temperatures through the cooling degree days (CDD). For example, the US has ~1,900 CDD, Europe has only ~300 CDD (resulting in ~30% of the per hospital energy use), and Asia has ~3,600 CDD (resulting in ~120% of the per hospital energy use).

    b. **Hospitals, Cooling degree days adjust based on 23˚C temp (25% weight).** Scenario 1a is a good baseline, but it may over-estimate the cooling needs as many countries have a diversity in buildings codes, interior temperature comfort expectations, and building typology variation. As a result, scenarios 1b and 1c adjust the comfort temperature (by 5 or 10 degrees C), reflecting these variations. For example, Europe's per hospital energy needs drop significantly by ~90%, while Asia and Africa's per hospital needs only drop slightly (15%). We believe scenario 1b is the most reflective of cooling expectations.

    c. **Hospitals, Cooling degree days adjust based on 28˚C temp (10% weight).** Scenario 1b outlined the concept behind this scenario; this takes a warmer view on what is defined as a comfortable temperature. Europe's per hospital energy needs drop significantly by ~95%, while Asia and Africa's per hospital needs drop by 30-40%.

2. **Method 2 (40% weight total, total CO_2-derived, with healthcare/hospital needs and cooling-degree days).** This top-down method is weighed moderately high. See Table 1 for the definition of low and high in the descriptions below.

    a. **High CO_2e scenario -not adjusted for cooling degree days (5% weight).** This scenario receives a lower weight because we believe it slightly over-estimates the true cooling needs because of using the estimates on the high end, but not reflecting that cooling need vary by country. For example, Russia, Canada, and Germany have high estimates in this scenario because their lower ambient temperatures are not accounted for.

b. **High CO_2e scenario – adjusted for cooling degree days (20% weight).** This receives the highest weight because we believe it is most representative. It starts with the higher estimates of cooling emissions, but then reflects the specific cooling needs of each country.

c. **Low CO_2e scenario – not adjusted for cooling degree days (10% weight).** This scenario receives the second-highest weight within the method because the lower-end estimates generally reflect a lower need, so there isn't a need to reduce the estimate to account for cooling differences across countries.

d. **Low CO_2e scenario -adjusted for cooling degree days (5% weight).** This scenario receives a low weight because, as noted in 2c, the lower-end estimates already reflect a lower cooling need, so adjusting again for CDD lowers the estimate artificially.

3. **Method 3 (10% weight total, space cooling for services energy-derived, with hospital-services).** This method overall is weighed very little because we believe that the IEA space cooling estimate is a significant underestimate. We did not, however, completely exclude this method to show the variation in using different sources.

   a. **Space-cooling, high services (7% weight).** We weighed the scenario with higher services more than the final low services scenario.

   b. **Space-cooling, low services (3% weight).**

Table 2: Summary of Methods and Scenarios (Mt CO_2e, totals rounded to the nearest 5)

Region	Country	Hospital Cooling	1a	1b	1c	2a	2b	2c	3a	3b	3c
	Total	365	395	290	265	555	620	325	355	80	40
China	China	85	122	65	65	127	126	76	76	14.9	7.5
North America	United States of America	55	41	41	41	81	81	64	64	27.7	13.9
India	India	25	31	27	23	19	30	12	19	4.4	2.2
Pacific	Japan	15	22	14	12	24	24	11	11	2.1	1.1
South/ Central America	Brazil	15	3	3	2	30	47	18	23	0.7	0.3
North America	Mexico	10	20	17	14	7	11	4	6	1.7	0.8
Europe	Russian Federation	10	1.5	1.0	1.0	28.5	28.3	17.1	17.1	1.2	0.6
Rest of Asia	Democratic People's Republic of Korea	5	14.1	12.1	10.1	0.6	0.9	0.3	0.5	0.1	0.1
Rest of Asia	Indonesia	5	8.0	7.2	6.1	5.0	7.7	3.2	5.0	1.0	0.5
Rest of Asia	Philippines	5	11.2	10.1	9.0	1.1	1.7	0.7	1.1	0.2	0.1
North America	Canada	5	0.4	0.2	0.2	17.0	16.8	7.3	7.3	0.3	0.1
Europe	Germany	5	0.8	0.6	0.6	15.7	15.6	6.8	6.8	1.0	0.5
Pacific	Australia	5	2.4	1.4	1.4	12.6	12.5	5.4	5.4	1.6	0.8
Rest of Asia	Thailand	5	6.2	5.3	4.4	4.5	7.0	2.7	4.1	0.5	0.2
All 179 others		115	113	88	75	184	211	97	111	25	12

About the Authors

Hovland Consulting LLC

Hovland Consulting helps foundations and non-profits improve the world's climate and communities. We specialize in climate change abatement, clean transportation, energy efficiency, and conservation of land, water, and the environment. We are adept at synthesizing diverse information using 1,000's of pieces of data from a wide variety of sources to create a single model that tells a compelling story. Using data-driven insights derived from strong analytics, research, modeling, expert input, and maps, Hovland Consulting helps clients make informed decisions, track and improve performance, facilitate growth, and invest wisely to achieve goals. Website.

Health Care Without Harm

Health Care Without Harm (HCWH) has been the leading health sector NGO working internationally on climate since 2009. HCWH works through regional offices in Asia, Europe, Latin America and the U.S., as well as through country-level partnerships with national organizations in multiple countries including Australia, Brazil, China, India, Nepal and South Africa. HCWH has a comprehensive set of partnerships with health organizations, health professionals, international organizations and government ministries, together with a global network of more than 1,000 institutions representing over 32,100 hospitals and health centers in 52 countries worldwide. Website.

NRDC

The Natural Resources Defense Council (NRDC) is an international environmental organization with more than 3 million members and online supporters. Since 1970, our scientists, lawyers and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC works in the United States, China, India, Canada, Latin America, as well as on global initiatives to address climate change, protect nature, and promote healthy people and thriving communities. In India, NRDC works with local partners on transformative solutions to advance clean energy and climate resilience. Website.

KIGALI COOLING EFFICIENCY PROGRAM

The Kigali Cooling Efficiency Program (K-CEP) is a philanthropic program to support the Kigali Amendment of the Montreal Protocol. Under the amendment, 197 countries committed to cut the production and consumption of hydrofluorocarbons – potent greenhouse gases used in refrigeration and air conditioning – by more than 80 percent over the next 30 years. K-CEP focuses on the energy efficiency of cooling to increase and accelerate the climate and development benefits of the Kigali Amendment to phase down HFCs. Website.