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Additional submitted attachment is included below.

CRAC unit layout, though this system better prevents cold and warm air from unintentionally mixing within the data center. When the outside air temperature is equal to or below the temperature of the air supplied to cool the server, the AHU can directly draw outside air into the data center and exhaust all of the return air after it has passed across the computer servers. The movement of 100% outside air through the system can require more fan energy than the baseline case, as the economizer design requires more ducting, which increases air resistance through the system. However, during this 100% outside air mode the cooling is provided without operating the chiller, chilled water pumps, condenser water pumps, or the cooling tower fans. Outside air is also provided instead of recirculated air whenever the outside air temperature is greater than the supply air temperature but lower than that of the return air. Under this condition the chiller must operate, but the cooling required of the chiller is less than in a case with complete recirculation.

Energy Modeling Protocol

For each design scenario, the model calculations assume a 30,000 ft^2 (2800 m^2) data center with an internal heat density of approximately 80 W/ft^2 (0.86 kW/m^2; 2.4 MW total) This size and power density are characteristic of data centers evaluated in previous studies (Shehabi et al. 2008; Greenberg et al. 2006; Tschudi et al. 2003). The size of data centers varies greatly; 30,000 ft^2 is within the largest industry size classification, which is responsible for most servers in the US (IDC 2007). Power density in data centers is rapidly increasing (Uptime Institute 2000) and a power density of 80 W/ft^2 is currently considered to be of low- to mid-range (Rumsey 2008).

Basic properties of the modeled data center for all three scenarios are summarized in Table 1. Energy demand is calculated as the sum of the loads generated by servers, chiller use, fan operation, transformer and uninterruptible power supply (UPS) losses, and building lighting. The chiller encompasses coolant compressor, chilled water pumps, condensing water pumps, humidification pumps, and cooling-tower fans. Energy demand for servers, UPS, and lighting are constant, unaffected by the different design scenarios, but are included to determine total building-energy use. The base case and WSE scenarios assume conventional humidity restrictions recommend by ASHRAE (ASHRAE 2005). The ASE scenario assumes no humidity restriction, which is an adjustment required to gain ASE benefits as is typical in ASE implementation (Rumsey 2008). Air-side economizers also require a different air distribution design and the fan parameters associated with each design scenario are listed in Table 2. The properties of other pumps and fans throughout the HVAC system remain constant for all three scenarios. Values are from previous data-center energy analyses (Rumsey 2008; Rumsey 2005).

Table 1. Data Center Characteristics Common to All Design Scenarios

Data Center Parameters	
Floor Area	30,000 ft^2
UPS Waste Heat	326 kW
Data Center Lights	30 kW
Total Rack Load	2000 kW
Total Internal Load	2,356 kW
Average Internal Load Density	79 W/ft^2
Minimum Ventilation	4,500 ft^3/min
Supply Air Temperature	55 ¡F
Return Air Drybulb Setpoint	72 ¡F
Chiller Capacity	1750 kW
Number of Chillers	3

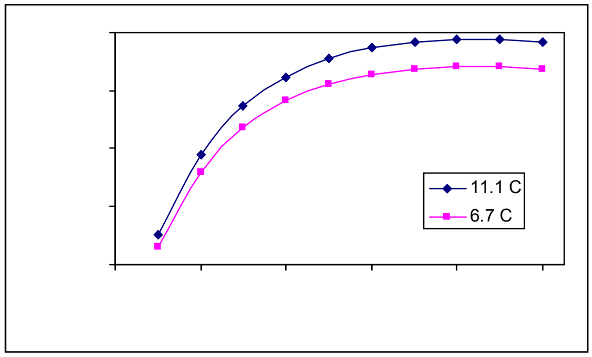
Table 2. Data Center Fan Properties

Fan System Parameters	Baseline and WSE			ASE	
	MUAH	Exhaust	CRACs	Supply	Relief
Total Air Flow (cfm)	4,500	4,500	495,000	437,758	437,758
Fan Motor Size, Nominal (hp)	7.5	3	10	30	50
Number of Fans	1	1	30	10	5
Fan Efficiency	53.3%	44.0%	55.6%	63.8%	67.5%
Fan Drive Efficiency	95%	95%	95%	95%	95%
Fan Motor Efficiency	89.6%	86.2%	90.1%	92.5%	93.2%
VFD Efficiency	n/a	n/a	n/a	98%	98%
Total Static Pressure Drop (in w.g.)	3.5	1	1.6	2	1

The energy modeling approach used in this study applies a previously used protocol (Rumsey 2008; Rumsery 2005) and is based on a combination of fundamental HVAC sizing equations that apply equipment size and efficiencies observed through professional experience. Building energy modeling is typically performed using energy models such as DOE-2, which simultaneously models heat sources and losses within the building and through the building envelope. However, models such as DOE-2 are not designed to incorporate some of the HVAC characteristics unique to data centers. Also, data centers have floor-area-weighted power densities that are 15-100 times higher than those of typical commercial buildings (Greenberg et al. 2006). This allows accurate modeling of data-center energy use to focus exclusively on internal heat load and the thermal properties of outdoor air entering the building. This is the approach taken in this study, as heat generated from data center occupants and heat transfer through the building envelope are negligible relative to the heat produced by servers. The building envelope may influence the cooling load in low-density data centers housed in older buildings that have minimal insulation. Evaluating this building type is worthy of exploration, but the required analysis is more complex and outside the scope of the present paper.

Both air-side and water-side economizers are designed to allow the chiller to shut down or reduce chiller energy load under appropriate weather conditions. Less overall energy is required for operation when the chiller load is reduced, but chiller efficiency is compromised. Changes in chiller efficiency used in this analysis are shown in Figure 2, representing a water-cooled centrifugal chiller with a capacity > 300 tons and condenser water temperature of 80 °F. A chilled water temperature of 45 °F, which is standard practice for data center operation, is used in the base case and ASE scenario. The WSE scenario uses a chilled water temperature of 52 °F, which is common when using water-side economizers. This increases needed airflow rates but allows greater use of the water-side economizers. The curves are based on the DOE2.1E software model and apply coefficients specified in the Nonresidential Alternative Calculation Method (ACM) Approval Manual for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (CEC 2005).

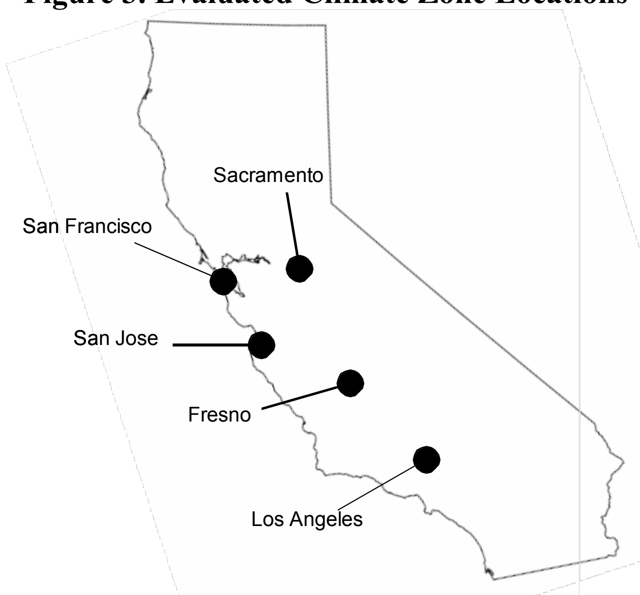
Figure 2. Assumed Part Load Performance of Data Center Chillers



Part load efficiencies for a water-cooled centrifugal chiller with a capacity >300 tons and an condenser water temperature of 26.7 °C (CEC, 2005))

Annual data center energy use is evaluated for each of the three configuration scenarios assuming that a data center building is located in each of the five cities shown in Figure 3. Weather conditions at each city are based on hourly DOE2.1E weather data for California climate zones (CEC 2005).

Figure 3. Evaluated Climate Zone Locations



Results and Discussion

Results from each scenario modeled are presented in Table 3 as a "performance ratio" which equals the ratio of total building energy divided by the energy required to operate the computer servers. Lower value of the performance ratio implies better energy utilization of the HVAC system. The performance ratio for the base case is 1.55 and, as expected, is the same for all the cities analyzed, since the operation of this design is practically independent of outdoor weather conditions. The base case performance ratio is better than the current stock of data centers in the US (EPA 2007; Koomey 2007) because the base case represents newer data centers with water-cooled chillers, which are more efficient than the air-cooled chillers and direct expansion (DX) cooling systems found in older data centers.

Table 3. Ratio of Total Building Energy to Computer Server Energy

	San Jose	San Francisco	Sacramento	Fresno	Los Angeles
Baseline	1.55	1.55	1.55	1.55	1.55
Air-side Economizer	1.44	1.42	1.44	1.46	1.46
Water-side Economizer	1.53	1.54	1.53	1.53	1.54

The performance ratios for the ASE and WSE scenarios show air-side economizers consistently provide savings relative to the base case, though the difference in savings between the two scenarios varies. It is important the note that even small changes in the performance ratio results in significant savings, given the large amount of energy used in data centers. For example, reducing the performance ratio at the model data center in San Jose from 1.55 to 1.44 represents a savings of about 1.9 million kWh/y, which corresponds to a cost savings of more than $130,000/y (assuming $0.07/kWh).

Figure 4 shows the disaggregation of the cooling systems' annual energy use, normalized by floor area, for each modeled data center by location and design scenario. The annual energy use dedicated to the servers, USP, and lighting is 584, 95, and 9 kWh/ft^2, respectively. These energy values are independent of the climate and HVAC design in scenario and not included in the graphs in Figure 4. Economizer use is typically controlled by combination of outside air temperature, humidity, and enthalpy; however results shown in Figure 4 are for economizer use controlled by outside air temperature only. Results show that the ASE scenario provides the greatest savings in San Francisco while Fresno provides the least ASE savings. Sacramento benefited the most from the WSE scenario while minimal savings were realized in Los Angeles and San Francisco. The San Francisco WSE scenario, where significant gains would be expected because of the cool climate, is hindered by chiller part-load inefficiencies. The relatively higher moisture content in the San Francisco air increases the latent cooling load in the model and causes the chiller plant to reach the capacity limit of the first chiller more often, activating a second chiller. The second chiller shares the cooling load equally with the first, resulting in a transition from one chiller at a high load factor (efficient operation) to two chillers at slightly above half the load factor (less efficient operation). The results from the WSE scenario in San Francisco emphasize the need for engineers to model the hour-by-hour load, rather than just the peak load, and to size chillers such that all active chillers at any moment will be running near their most efficient operating point.

Figure 4. Disaggregated Energy Use (Climate Dependent Values Only)

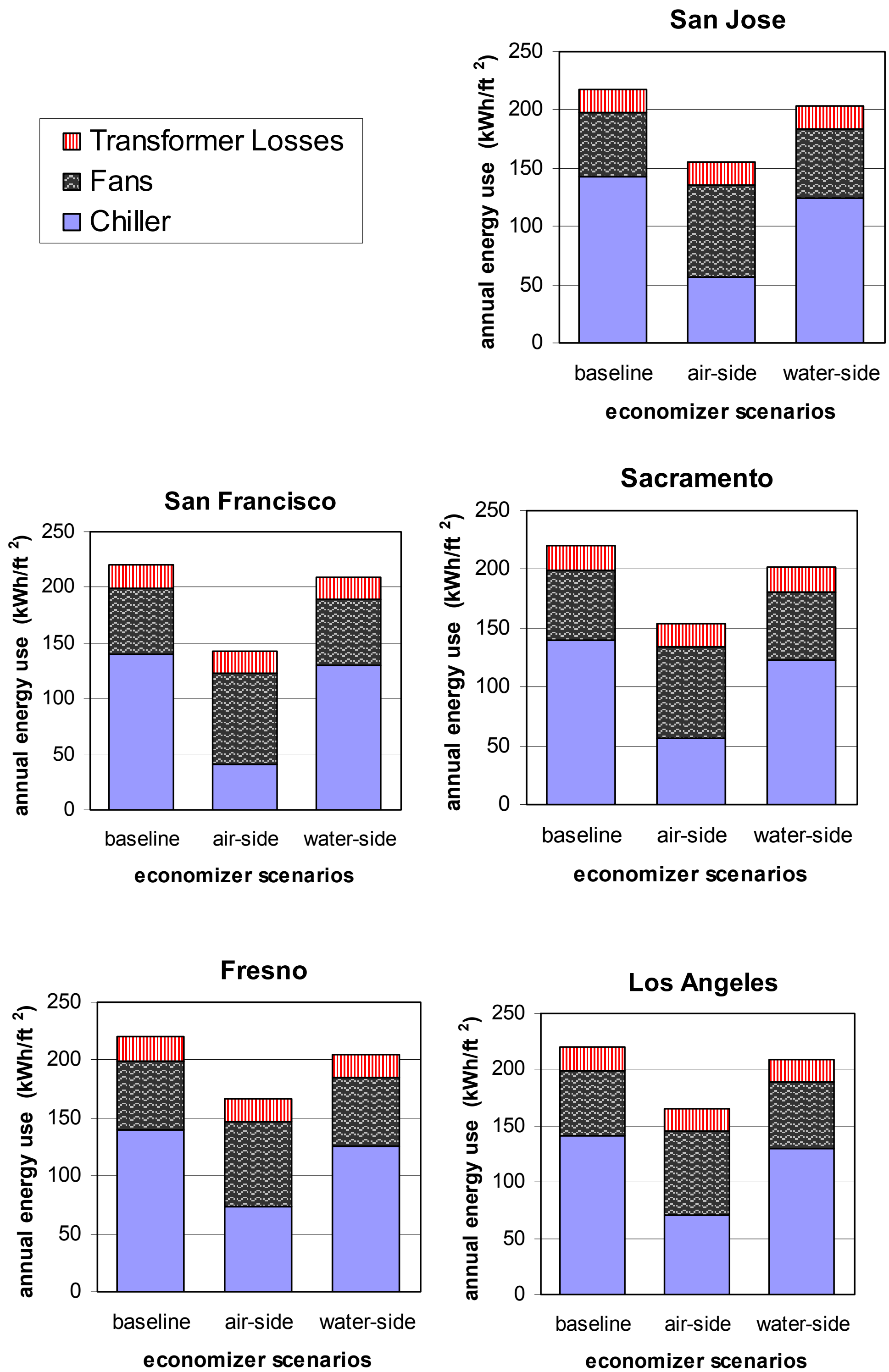
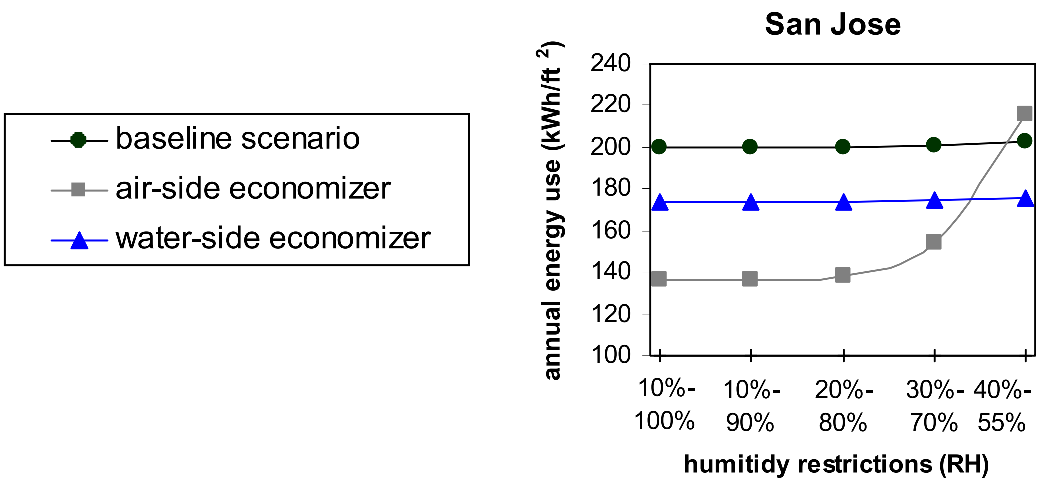
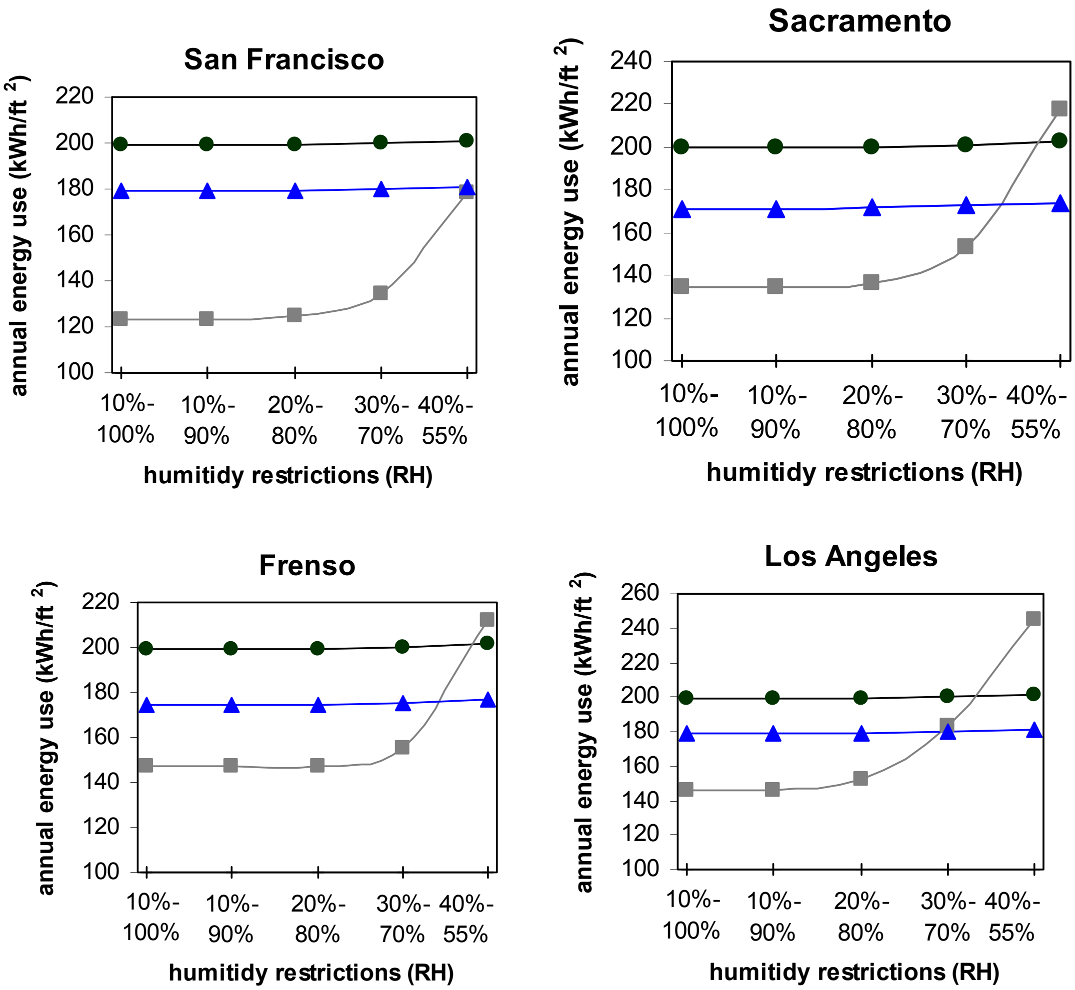


Figure 5 shows that removing the humidity restrictions commonly applied to data centers is necessary to gain ASE energy savings. As the relative humidity (RH) ranged is narrowed, energy use from the fans begins to sharply increase, surpassing the equivalent baseline energy in most of the cities. Humidity levels are often restricted in data centers to minimize potential server reliability issues. ASHRAE's guidelines released in 2005 for data centers provide a "recommend" RH range between 40-55% and an "allowable" range between 20-80% (ASHRAE 2005). There is minimal cost in applying the more conservative ASHRAE RH restrictions in conventional data center design, such as the baseline in this study shown in Figure 5. The influence of humidity on server performance, however, is poorly documented and the need for humidity restrictions is increasingly being questioned (Fontecchio 2007). The energy saving difference between adhering to ASHRAE's recommend RH range versus the allowable RH range is substantial, and warrants further investigation.

Figure 5. Chiller and Fan Energy Resulting from Humidity Restrictions





Conclusion

Employing the energy-saving measures evaluated in this paper would require a shift in conventional data center design and operation. Various operational concerns must be addressed before widespread adoption of these technologies could be expected in data-center buildings. This paper contributes to the informed implementation of air-side and water-side economizers by assessing the energy benefits of adopting these efficiency improvements. Air-side economizers are shown to consistently outperform water-side economizers in California, though the difference in performance varies by the climate conditions of the locations evaluated. Furthermore, the models show that conventional humidity restrictions must by relaxed or removed to substantially realize the energy benefits of air-side economizers. As the data center economy continues to rapidly grow, energy efficiency will continue to emerge as an important financial and environmental concern. The results presented here contribute to our understanding of different design implications and should assist decision makers in the implementation of energy-efficient data centers.

Acknowledgments

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Data centers environmental impact assessment features

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Abstract. Data centers became significant sources of environmental impact: each year global data centers consume TWh of electricity, generate comparable thermal emissions to the atmosphere and/or hydrosphere, create wastes of electronic equipment and life-expired batteries, and create other types of direct and indirect ecological footprint. In conformity with the sustainable development concept data centers environmental impact of all types should be numerically assessed to compare to the environmental capacity and move towards sustainability. It requires ecological footprint (carbon footprint in particular) to be assessed. Existing xUE Effectiveness Metrics used for data centers are all relative, so data centers' environmental impact cannot be calculated directly from it. Methods of payment calculation for negative environmental impact, used in Russia, do not take into account data center features and can hardly be used for the assessment tasks. Data centers need to adapt existing and develop new assessment methods for its environmental impact, considering all the resources consumed and all the emissions generated.

1 Introduction

Data centers consume large amounts of electricity. Sources may differ in their estimates: according to [1] datacenter annual global electricity consumption in 2010-2018 increased from 194 TWh to 205 TWh, while [2] states that it already achieved 286 TWh in 2016. However, sources agree that datacenter consumption is hundreds of TWh per year, which is 1-1.5% of total world electricity production. There is a trend to growth of datacenter energy consumption, and one of the reasons is data centers number increase caused by the ICT development in general and the Internet of Things spreading in particular. Thus, the largest Russian data center (Rostelecom, Udomlya) with its 1st stage of 40 MW power consume 0.65 TWh annually. Total number of data centers increases all over the world including Russia; new facilities appear and some existing facilities expand. Based on existing trends [2] forecasts world datacenter consumption will achieve 321 TWh/year by 2030.

The major part of the electricity consumed by data centers converts to thermal energy and comes to the environment: to the atmosphere when using air cooling, to the atmosphere

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and/or the hydrosphere when using liquid cooling systems [3]. In addition to thermal environmental pollution directly generated by data centers, these facilities are responsible for emissions occurring at electricity generating plants, energy from which is then consumed by data centers. As carbon quota develops, this aspect should be estimated and taken under control.

In case of centralized energy supply failure data centers use backup power supplies, which also have an environmental impact. Diesel generators able to power datacenter facilities have the output comparable to the same MW data center power, which means dozens tons of diesel fuel consumed per day. Hydrocarbon fuel combustion results in direct CO_2 emissions. Also some less significant emissions of carbon monoxide, nitrogen oxides, unburned hydrocarbons etc. take place.

In case of cooling agent leakage or fire extinguishing system activation liquid, gaseous and solid (powder) emissions/wastes can take place. Some of them are considered pollutants. Depending on systems used these can be: ethylene glycol, "waterless water/dry water" organic compounds (fluorinated ketones), halocarbons (CFCs, HFCs) etc. In case of carbon dioxide fire extinguishing system activation direct emission of CO_2 takes place.

Data centers also create solid wastes: electronic equipment (out of order or obsolete), storage media (including deliberately destroyed to keep confidentiality of information, although their lifetime has not expired yet), and life-expired/lost capacity batteries.

Sustainable development principles applied to data centers functioning mean that all the forms of datacenter environmental impact must be numerically assessed to compare it to environment capacity. Meanwhile numerical criteria data centers currently use do not correspond to this task, despite the fact some of them are called *Sustainability Metrics* [4-5].

2 Materials and methods

PUE (*Power Usage Effectiveness*) metric offered by The Green Grid [6] in 2007 is widely used to assess data center efficiency. Initially it was calculated as follows:

$$PUE = Total\ Facility\ Power\ /\ IT\ Equipment\ Power \tag{1}$$

Later sources [7] use corrected formula:

$$PUE = Total\ Facility\ Energy\ /\ IT\ Equipment\ Energy =$$
$$= 1 + Non\ IT\ Facility\ Energy\ /\ IT\ Equipment\ Energy \tag{2}$$

Created to assess the efficiency of datacenter energy consumption, PUE assumes the closer is the metric to 1 the greater is the share of energy consumed by the target IT equipment (and the less by the auxiliary engineering subsystems). But neither the initial nor the corrected PUE metric report anything on the energy consumption absolute value and the associated environmental impact. All PUE metrics are relative. By the time the PUE was proposed, the ecological footprint and carbon footprint terms had already been developed. But none of them can be calculated or assessed from the PUE metric as it is.

Different data centers calculate PUE in different ways, excluding some engineering subsystems from consideration, which leaves a wide field for manipulation [8]. For example, the numerator may exclude the energy consumed by cooling systems (which is comparable to the IT equipment consumption itself) if the data center "receives cold" from an external supplier. The denominator can be artificially inflated by indicating the consumption declared in the IT equipment specifications instead of the actual consumption. Such manipulations make it difficult to compare different data centers to each other, thus

PUE cannot be used for practical purposes and cannot serve as a basis for sustainable development implementation [9-10].

WUE (*Water Usage Effectiveness*) and CUE (*Carbon Usage Effectiveness*) metrics offered by The Green Grid in 2010 are intended to assess respectively the efficiency of the water use and carbon fuel use in data centers [4-5]. But these as well as other xUE (*X Usage Effectiveness*) metrics are relative, all based on the ratio of the water consumed per year, carbon dioxide emissions per year and other material flows attributable to the entire facility, to the IT equipment energy consumption:

$$WUE = Annual\ Water\ Usage\ /\ IT\ Equipment\ Energy \tag{3}$$

$$CUE = Total\ CO_2\ emissions\ caused\ by\ Total\ Data\ Center\ Energy\ /\ /\ IT\ Equipment\ Energy \tag{4}$$

Despite the units these metrics use – l/kWh for WUE and kg or g of CO_2/kWh for CUE – none of them contain the information on the material and energy resources consumed by the data center. So these metrics cannot be used to assess datacenter environmental impact. At the same time it should be mentioned that WUE and CUE formulas include coefficients that characterize the sources of energy consumed by the data center:

— EWIF (*Energy Water Intensity Factor*), l/kWh, depends on the energy generation facility, which can be own (situated on the datacenter site) or external (owned by third-party suppliers);

— CEF (*Carbon Emission Factor*), kg or g of CO_2/kWh, depends on carbon fuel used for energy generation.

$$\begin{aligned} WUE_{source} &= (Annual\ Source\ Energy\ Water\ Usage + Annual\ Site\ Water\ Usage)\ /\ \\ &\ /\ IT\ Equipment\ Energy = \\ &= EWIF \times PUE + Annual\ Site\ Water\ Usage\ /\ IT\ Equipment\ Energy \end{aligned} \tag{5}$$

$$CUE = CEF \times PUE \tag{6}$$

If data centers will regularly collect and publish data on the energy sources used and the amount of resources consumed, then EWIF and CEF factors will allow calculating the actual emissions and assessing datacenter environmental impact.

Table 1. CO_2 emissions per kWh of energy obtained from carbon fuel combustion.

Fuel	**CEF, kg of CO_2/kWh** (IPCC data)
Coal	0.863 to 0.941
Brown coal	up to 1.175
Petroleum	0.893
Natural gas	0.491 to 0.891 depending on generation technology
	CEF, kg of CO_2/kWh (IPCC and EPA data, Russian sources, and authors' own estimates)
Unknown source, average	0.59 – 0.8

Recent years the estimates or carbon dioxide emissions associated with hydropower have been revised upward, from close to zero to dozens of grams of CO_2 per 1 kWh. The most reasonable estimate for today is made by Chinese authors [11]: 0.092 kg of CO_2/kWh. One can expect that detailed scientific analysis will change values currently assumed by

International Energy Agency for nuclear power as 0.004-0.012 kg of CO_2 per 1 kWh, to higher values.

Table 2. Water consumption per kWh of energy obtained from different sources.

Method used for electricity generation	**EWIF, l/kWh** (The Green Greed recommendations)	**Note**
Hydropower	0	Water is used for electricity generation but not consumed; all the water is available for future consumption
Coal combustion	2.2 to 2.8	
Nuclear power	3.3	
Natural gas combustion	0.8	

When generating electricity locally at the data center site, emissions to the environment can be estimated based on the amount of fuel consumed.

Table 3. CO_2 emissions per carbon fuel unit.

Fuel	**Specific carbon footprint** (EPA and IPCC data, other international sources)	**Specific carbon footprint** (Russian sources and authors' own estimates)
High-octane gasoline	1.93 to 2.35 kg of CO_2/l	2.39 kg of CO_2/l
Diesel fuel	2.64 to 2.69 kg of CO_2/l	2.69 kg of CO_2/l
Natural gas	1.90 to 1.94 kg of CO_2/m^3	1.98 kg of CO_2/m^3

Main resources for typical data center, its emissions and wastes are shown in Figure 1 as input and output flows.

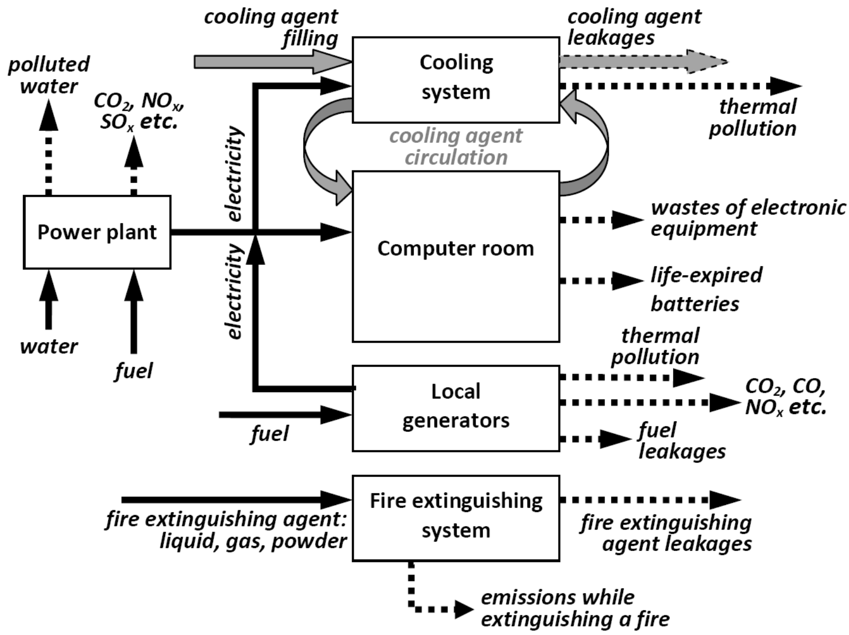

Fig. 1. Data center main resources, emissions and wastes.

Some of material/energy flows and environmental impacts shown in Figure 1 can be estimated by existing methods as shown below.

2.1 Numerical assessment for some types of datacenter environmental impacts

Taking into account different data centers sizes as well as the modular design used for medium and large facilities, it is advisable to perform the assessment per 1 module, which has a certain degree of autonomy: a separate computer room; dedicated cooling and fire extinguishing systems; UPS system based on electrochemical power source etc. The use of local generators can also be assessed per 1 datacenter module. A typical module size of 200 racks with 5 kW power per rack corresponds to total power of 1 MW. The assessment for sites of a different size and power can be performed proportionally.

2.1.1 Environmental impact as a result of electricity consumption obtained from external sources as well from local generation

1 MW datacenter module consumes 8.76 GWh of electricity annually. Current carbon footprint concept assumes that carbon dioxide emissions associated with the electricity consumed are the responsibility of the consumer. If we know the type of power plant delivering the energy to the data center, we can estimate CO_2 emissions in accordance with Table 1. If the source is unknown, the annual emissions can vary from 5,168.4 to 7,008 t CO_2 per 1 MW of datacenter power.

Current payment rates in Russian Federation for pollutants emission into the atmosphere from stationary sources [12] and calculation methods applied do not consider carbon dioxide as an environmental pollutant. A carbon quota and carbon footprint payment system has yet to be developed, both internationally and locally.

As noted before, the major part of the electricity consumed by data centers converts to thermal energy and comes to the atmosphere and/or the hydrosphere. Despite the datacenters heat emission of dozens and hundreds GWh per year, current methods to assess the environmental impact of industrial facilities in Russian Federation do not take heat emissions into account and do not consider necessary any payments for thermal pollution. Payment rates development can base on the ratio of 8.76 GWh/year of thermal emission per each 1 MW of datacenter power.

In addition to CO_2 emission power plants of different types can be responsible for NOx/SOx oxides and other pollutants emissions, as well as for certain water consumption. However, the responsibility for such types of environmental impact, unlike the carbon footprint, is not shifted to the consumer. Energy facilities of the Russian Federation make regular payments to the budget in accordance with the payment rates for negative environmental impact [12].

The calculation methods used for energy facilities can be applied to a certain extent to local datacenter electricity generation processes. Payment rates list for pollutants emission to the atmosphere from stationary sources includes some substances contained in the exhaust gases of diesel generators and other generating units (see Table 4). Calculations are made in rubles per 1 ton of pollutants, and the rates are set each year by corresponding Governmental Regulation. Thus, in 2021 one should use payment rates set for 2018 by a factor of 1.08.

The amount of such pollutants emission per unit of fuel consumed can be estimated based on the specific generating equipment data sheets.

Table 4. Payment rates for pollutants emission to the atmosphere from stationary sources [12].

Pollutant	**Payment rates per 1 ton of pollutant (Russian Federation rubles)**		
	2016	**2017**	**2018**
Nitrogen dioxide	133.1	138.8	138.8
Nitrogen oxide	89.6	93.5	93.5
Carbon monoxide	1.5	1.6	1.6
etc.	…	…	…

Payments taken in past for diesel and other fuels emission to the environment, for emission of unburned hydrocarbons were canceled in Russian Federation due to the use of an excise tax on automobile and diesel fuel, to avoid double payments for negative environmental impact. In fact any data center pays for such an impact at the time of diesel fuel purchase, but it is still necessary to track these emissions in order to plan actions to reduce the environmental impact whatever it is [13, 14].

Based on the average technical specifications for 1000 to 5000 kW diesel generator units, about 280 l/h of diesel fuel is required to support 1 MW target equipment operation, which leads to 0.75 t of CO_2/h emission. Local generation is intended to provide electricity supply in case of emergency and failure of external electricity supplies. Such periods can hardly exceed several hours a year.

Thermal pollution can be estimated through the diesel fuel specific heat of combustion, which is 42.7 MJ/kg: most of the energy will convert directly to thermal form at electricity generation stage; the rest will do the same after the generated electricity is used by data center IT equipment and auxiliary engineering systems. When using diesel generators, 2.8 MWh of low-grade thermal energy will be emitted to the environment every hour per each 1 MW of datacenter power.

2.1.2 Environmental impact as a result of cooling and fire extinguishing agents' leakages

Payment rates [12] for pollutants emission to the atmosphere and discharge to natural water bodies mention only some of the substances used in the data center, which can be subject to leakages during normal operation and emissions in case of failure or fire: ethylene glycol, some freons, the simplest ketones etc. The rates do not list: fluorinated ketones (which include "dry water" Novec 1230), some HFCs/halons and other organic substances used as fire extinguishing agents, powder/aerosol fire extinguishing agents. Payment rates for such substances emission to the environment should be developed in future.

Taking into account the reserve cooling agent containers capacity in datacenter modules, possible leakage/emissions can hardly exceed 30 m^3 (20 – 30 t depending on agent density) per 1 datacenter module for liquids and an equivalent mass for agents converting to gas.

Gas agent emission in case of extinguishing a fire in a datacenter module can be determined through an average normative volume fire extinguishing concentration ~10%. 200 racks datacenter module of 600 m^2 average area and 6 m ceiling height will require more than 360 m^3 of gas fire extinguishing agent.

Noble gases, nitrogen, their mixtures (argonite, etc.) are not considered as environmental pollutants regardless the size of emission. In case carbon dioxide is used as a fire extinguishing agent or forms a part of a mixture (e.g. inergen), this must be taken into account as a direct CO_2 emission to the environment. Emissions can reach 0.72 t of CO_2 per extinguishing a fire in 1 datacenter module. In case of CFCs/HFCs fire extinguishing agents not only payment rates for emission to the environment must be used, but also the probable ozone depleting effect must be taken into account.

2.1.3 Wastes of electronic equipment and life-expired electrochemical power sources (batteries)

Average 5-10 year lifetime of electronic IT equipment, servers, storage systems, battery UPS systems and the batteries themselves means annual depreciation of 20-10% respectively. Thus solid waste flows can be estimates in t/year per 1 datacenter module. Datacenter 45U racks average filling with 15 kg/U IT equipment means 6.8 – 13.5 t of electronic equipment become out of operation each year. The existing payment rates for solid wastes disposal [12] classify electronic boards as Hazard class IV (low hazard) wastes.

Table 5. Payment rates for wastes disposal [12].

Waste types	**Payment rates per 1 ton of wastes (Russian Federation rubles)**		
	2016	**2017**	**2018**
Hazard class I of wastes (extreme hazard)	4452,4	4643,7	4643,7
Hazard class II of wastes (high hazard)	1908,2	1990,2	1990,2
Hazard class III of wastes (moderate hazard)	1272,3	1327	1327
Hazard class IV of wastes (low hazard)	635,9	663,2	663,2

Batteries, depending on their type, are classified as Hazard class II or III wastes. With the average weight of 18 kg/kW for battery equipped UPS systems (based on data sheets), able to maintain the equipment operation for several minutes required for local generators to start and reach a stable operating mode, the laden weight of the UPS system can be determined per 1 MW of datacenter power: 18 t. Thus the weight of out of operation equipment can be 1.8 – 3.6 t/year.

Electronic equipment and batteries recycling is currently at an early development stage. The processing is energy intensive, implies the use of large amounts of acids and other substances. On the one hand, the recycling can reduce datacenter operation ecological footprint and turn the solid wastes to raw materials for processing plants. On the other hand, the economic and resource benefits of precious and rare metals extraction from electronic wastes can be accompanied by a significant negative environmental impact from the processing enterprises themselves, which should be the subject of further study and assessment.

3 Results and discussion

The assessment results are shown in Table 6.

Table 6. Assessment results for datacenter environmental impacts.

Impact originator	**Impact magnitude**				
	Carbon footprint or wastes	**Thermal emission**	**Non CO_2 emission to the atmosphere**	**Discharge to natural water bodies**	**Solid wastes disposal**
Electricity consumption from external sources	5 168.4 – 7 008 t of CO_2/year /MW	8.76 TWh/year/MW	–	–	–
Local electricity generation	0.75 t of CO_2/h /MW	2.8 MWh/h/MW	*Payment included in fuel excise tax*	–	–
One-time cooling agent leakage	–	–	< 30 m^3 of liquid/module, max. 20 – 30 t/module, the substance list in [12] is not comprehensive		–
One-time fire extinguishing agent emission in case of fire	< 0.72 t of CO_2/module	–	> 360 m^3, the substance list in [12] is not comprehensive	–	–
Electronic equipment wastes	6.8 – 13.5 t/year/module	–	–	–	Hazard class IV of wastes

Table 6. Continued.

Impact originator	**Impact magnitude**				
	Carbon footprint or wastes	**Thermal emission**	**Non CO_2 emission to the atmosphere**	**Discharge to natural water bodies**	**Solid wastes disposal**
Life-expired batteries	1.8 – 3.6 t/year/module	–	–	–	Hazard class II or III of wastes
	No existing payment rates	No existing payment rates	Payment rates partly developed	Payment rates partly developed	Payment rates do not take into account specific character of datacenter wastes

Values in Table 6 allow assessing the datacenter negative environmental impact based on certain data center power, modules quantity, the number of hours of local generation power supply and one-time cases of leakages/fires. As statistics on datacenter operation accumulate, emissions can be estimated more accurately.

4 Conclusion

Sustainable development requires all the datacenter environmental impacts to be quantified and controlled to create economic and other incentives to reduce datacenter effects on the biosphere. To achieve this goal it is extremely important that data centers regularly publish statistics on resource consumption of all types, indicating their sources, flow sizes in absolute form, as well as technical characteristics of the corresponding equipment.

It is necessary to develop payment rates for the carbon footprint and thermal pollution and complement the existing lists of pollutants, indicating corresponding payment rates for emissions to the atmosphere, discharge to natural water bodies, and solid wastes disposal.

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The environmental footprint of data centers in the United States

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Supplementary material for this article is available online

Abstract

Much of the world's data are stored, managed, and distributed by data centers. Data centers require a tremendous amount of energy to operate, accounting for around 1.8% of electricity use in the United States. Large amounts of water are also required to operate data centers, both directly for liquid cooling and indirectly to produce electricity. For the first time, we calculate spatially-detailed carbon and water footprints of data centers operating within the United States, which is home to around one-quarter of all data center servers globally. Our bottom-up approach reveals one-fifth of data center servers direct water footprint comes from moderately to highly water stressed watersheds, while nearly half of servers are fully or partially powered by power plants located within water stressed regions. Approximately 0.5% of total US greenhouse gas emissions are attributed to data centers. We investigate tradeoffs and synergies between data center's water and energy utilization by strategically locating data centers in areas of the country that will minimize one or more environmental footprints. Our study quantifies the environmental implications behind our data creation and storage and shows a path to decrease the environmental footprint of our increasing digital footprint.

1. Introduction

Data centers underpin our digital lives. Though relatively obscure just a couple of decades prior, data centers are now critical to nearly every business, university, and government, as well as those that rely on these organizations. Data centers support servers, digital storage equipment, and network infrastructure for the purpose of large-scale data processing and data storage [1]. Increasing demand for data creation, processing, and storage from existing and emerging technologies, such as online platforms/social media, video streaming, smart and connected infrastructure, autonomous vehicles, and artificial intelligence, has led to exponential growth in data center workloads and compute instances [2].

The global electricity demand of data centers was 205 TWh in 2018, which represents about 1% of total global electricity demand [3]. The United States houses nearly 30% of data center servers, more than any other country [3–5]. In 2014, 1.8% of US electricity consumption was attributable to data centers, roughly equivalent to the electricity consumption of New Jersey [1]. Previous studies found power densities per floor area of traditional data centers almost 15–100 times as large as those of typical commercial buildings [6], and data center power density has increased with the proliferation of compute-intensive workloads [7]. Though the amount of data center computing workloads has increased nearly 550% between 2010 and 2018, data center electricity consumption has only risen by 6% due to dramatic improvements in energy efficiency and storage-drive density across the industry [1, 3]. However, it is unclear whether energy efficiency improvements can continue to offset the energy demand of data centers as the industry is expected to continue its rapid expansion over the next decade [8].

The growing energy demand of data centers has attracted the attention of researchers and policymakers not only due to scale of the industry's energy use but because the implications the industry's

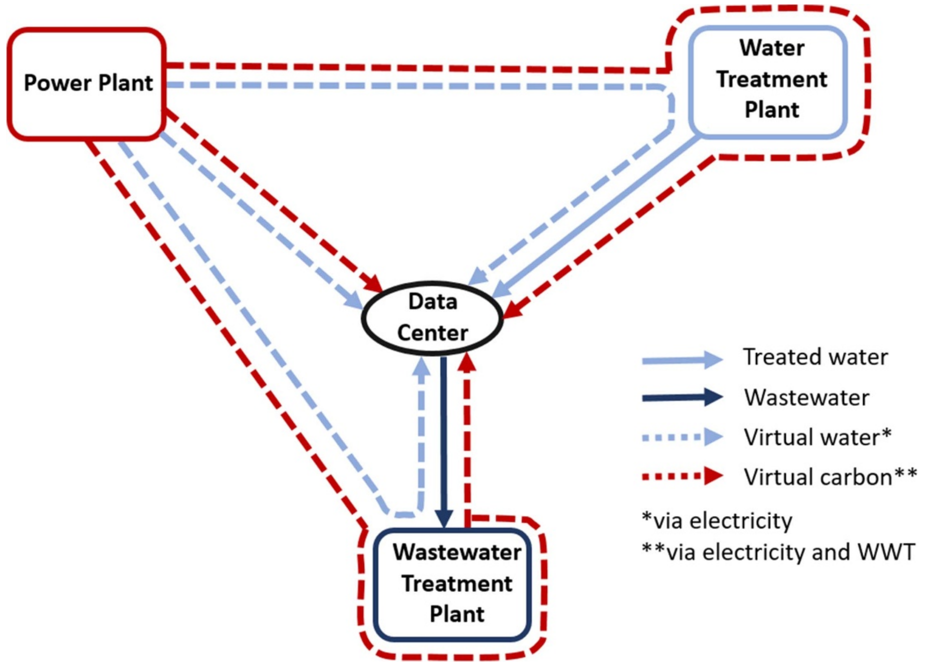

Figure 1. The system boundaries and interlinkages defining the operational water and carbon footprints of data centers. Specific power plants, water utilities, and wastewater treatment (WWT) utilities are connected to each data center through their provisioning of electricity and water. Power plants emit GHGs and consume water in the production of electricity. These environmental impacts are attributed to data centers in proportion to how much electricity the data center uses (red and blue dashed lines connecting facilities). The GHG emissions and water consumption associated with the provisioning of treated water and disposal of wastewater, including the GHGs and water consumed in the generation of the electricity supplied to these facilities, are also attributed to data centers in proportion to their use of these utilities. Data centers do not directly emit GHGs but they do directly consume water to dissipate heat. All these facilities work together to keep data centers operational and contribute to the water and carbon footprint of data centers.

energy consumption has on greenhouse gas (GHG) emissions and water use. Data centers directly and indirectly consume water and emit GHG in their operation. Most data centers' energy demands are supplied by the electricity grid, which distributes electricity from connected power plants. Electricity generation is the second largest water consumer [9] and the second largest emitter of GHGs in the US [10]. These environmental externalities can be attributed to the place of energy demand using several existing approaches [11, 12].

In addition to the electricity consumed directly by data centers, electricity is used to supply treated water to data centers and treat the wastewater discharged by data centers. Like data centers, water and wastewater facilities are major electricity consumers, responsible for almost 1.8% of total electricity consumption in the US in 2013 [13]. The electricity required in the provisioning and treatment of water and treatment of discharged wastewater also emits GHGs that can be attributed to data centers. Likewise, water used to generate the electricity used by water and wastewater utilities in their service of data centers contributes to the water footprint of these data centers. Water is also used directly within a data center to dissipate the immense amount of heat that is produced during its operation.

The geographic location [14, 15] and the local electricity mix [16] are strong determinants of a data center's carbon footprint, though these spatial details are often excluded in data center studies. A preliminary water footprint assessment of data centers by Ristic *et al* [17] provided a range of water footprints associated with data center operation. Although Ristic *et al* provided general estimates based on global average water intensity factors, their study highlights the importance of considering both direct and indirect water consumption associated with data center operation. Moreover, Ristic *et al* highlights the importance of considering the type of power plants supplying electricity to a data center and the type/size of a data center, as each of these factors can significantly impact energy use and indirect water footprint estimates.

In this study we utilize spatially-detailed records of data center operations to provide the first subnational estimates of data center water and carbon footprints. Here, water footprint is defined as the consumptive blue water use (i.e. surface water and groundwater). The carbon footprint of a data center, expressed as equivalent CO_2, is used to represent its global warming potential. Our assessment focuses on the operational environmental footprint of data centers (figure 1), which includes the power plant(s), water supplier, and wastewater treatment plant servicing the data center. The non-operational stages of a data center's life cycle (e.g. manufacturing of servers) consume relatively much less energy [18] and are excluded in this study. The spatial detail afforded by our approach enables more accurate estimates of water consumption and GHG emissions associated with data centers than previous studies. Moreover, we evaluate the impact of data center operation on the local water balance and identify data centers located in, or indirectly reliant upon, already water stressed watersheds. We investigate the following questions: (i) What is the direct and indirect operational water footprint of US data centers? (ii) Which watersheds support each data center's water demand and what portion of these watersheds are water stressed? (iii) How much GHG emissions are associated with the operation of data centers? (iv) To what degree can strategic placement of future data centers within the US reduce the industry's operational water and carbon footprints?

2. Methods

We utilize spatially detailed records on data centers, electricity generation, GHG emissions, and water consumption to determine the carbon footprint and water footprint of data centers in the US. Our approach connects specific power plants, water utilities, and wastewater treatment plants to each data center within the US. All data used in this study are for the year 2018, the most recent year where all data are publicly available. A visual summary of our methods is shown in supplementary figure S1 (available online at stacks.iop.org/ERL/16/064017/mmedia).

2.1. Data center location and energy use

Information availability on data center location and size varies depending on its type and owner. Ganeshalingam *et al* [4] reports likely locations of in-house small and midsize data centers, which house approximately 40% of US servers. Detailed information on colocation and hyperscale data centers is derived from commercial compilations [19–21] that get direct support and input from data center service providers.

We classified data centers based on the International Data Corporation classification system (summarized in table S1) and estimated the electricity use based on data center floor space. We used IT load intensity values (IT_s in watt/ft^2) for different data center types (s) from Shehabi *et al* [22] to estimate the total energy requirements (DC_E_{total}; in MWh) of colocation and hyperscale data centers as follows:

$$DC\_E_{\mathrm{total}} = IT_s \times PUE_s \times A \tag{1}$$

where PUE_s is the power usage effectiveness of space type s, and A is the floor area of data center in ft^2. We account for potential overstatement of data center capacity [4], a lack of distinction between gross and raised floor area, and unfilled rack capacity by scaling our server counts to match the 2018 estimate of servers by data center type [3], as shown in table 1 and figure S2. Scaled server estimates are then spatially distributed in proportion to the current spatial distribution of installed server bases. The number of servers by state is shown in figure S2.

Power usage effectiveness (PUE) is a key metric of data center energy efficiency [23]. A value of 1.0 is ideal as it indicates all energy consumed by a data center is used to power computing devices. Energy used for non-computing components, such as lighting and cooling, increases the PUE above 1.0 (see equation (2)). Generally, a data center's PUE is inversely proportionate to its size since larger data centers are better able to optimize their energy usage. Average PUE values and energy use by data center type were taken from Masanet *et al* [3] and shown in table 1 and table S1.

$$PUE = \frac{\text{Total power supplied to the data center}}{\text{Power consumed by the IT equipment}}. \tag{2}$$

2.2. Electricity generation, water consumption, and GHG emissions

Power plant-specific electricity generation and water consumption data come from the US Energy Information Administration (EIA) [24]. Of the approximately 9000 US power plants, the EIA requires nearly all power plants report electricity generation. However, only power plants with generation capacity greater than 100 MW (representing three-fourths of total generation) must report water consumption. We assigned national average values of water consumption per unit of electricity generation by fuel type (i.e. water intensity; m^3 MW h^{-1}) to all power plants with unspecified water consumption. Operational water footprints of solar and wind power were taken from Macknick *et al* [25]. Following Grubert [26], we assign all reservoir evaporation to the dam's primary purpose (e.g. hydropower). We connected hydroelectric dams with their respective power plants using data from Grubert [27]. Reservoir specific evaporation comes from Reitz *et al* [28].

The U.S. Environmental Protection Agency's eGRID database [29] provided GHG emissions associated with each power plant. GHG emissions are converted to an equivalent amount of carbon dioxide (CO_2)-eq with the same global warming potential so to derive a single carbon footprint metric [30]. Direct GHG emission during the operation of data centers are negligible [18] and therefore not considered in this study.

Data centers, water suppliers, and wastewater treatment plants typically utilize electricity generated from a mix of power plants connected to the electrical grid. Within the electrical grid, electricity supply matches electricity demand by balancing electricity generation within and transferred into/out of a power control area (PCA). Though it is infeasible to trace an electron generated by a particular power

Table 1. Combined direct and indirect water consumption and GHG emissions (carbon equivalence) by data center type. Water intensity and carbon intensity are reported per MWh of electricity used and per computing workload. Better energy utilization, more efficient cooling systems, and increased workloads per deployed server has increased the water efficiency of larger data centers. Computing workloads in hyperscale data centers are almost six times more water efficient compared to internal data centers. Workload estimates are based on traditional and cloud workloads from [2, 3].

Category	Energy use (million MWh)	Computing workloads (million)	Water intensity (m^3 MWh^{-1})	Carbon intensity (ton CO_2-eq MWh^{-1})	Water intensity (m^3/workload)	Carbon intensity (ton CO_2-eq/ workload)
Internal	26.90	16	7.20	0.45	12.15	0.75
Colocation	22.40	41	7.00	0.42	3.85	0.25
Hyperscale	22.85	76	7.00	0.44	2.10	0.15

plant to the final electricity consumer, there are several approaches to relate electricity generation to electricity consumption (Siddik *et al* [31] summarizes the most common approaches).

Here, we primarily rely on the approach used by Colett *et al* [32] and Chini *et al* [33] to identify the generative source of electricity supplied to any given data center. This approach assesses electricity generation and distribution at the PCA level where it is primarily managed. PCA boundaries are derived from the Homeland Infrastructure Foundation level data [34] and crosschecked against Form EIA-861 [35], which identifies the PCAs operating in each state. Annual inter-PCA electricity transfers reported by the Federal Energy Regulatory Commission [36] are also represented within this approach. A data center (as well as water and wastewater utilities) draws on electricity produced within its PCA, unless the total demand of all energy consumers within the PCA exceeds local generation, in which case electricity imports from other PCAs are utilized. If a PCA's electricity production equals or exceeds the PCA's electricity demand, it is assumed all electricity imports pass through the PCA and are re-exported for utilization in other PCAs. Siddik *et al* [31] notes that water and carbon footprints are sensitive to the attribution method used to connect power plants to energy consumers. Therefore, we conduct a sensitivity analysis (see the supporting information for additional details) to test the degree to which our electricity attribution method affects our results. Additionally, we also test different assumptions regarding the water footprint of hydropower generation, as this too is a key source of uncertainty.

We focus on the annual temporal resolution and assume an average electricity mix proportional to the relative annual generation of each contributing power plant. Though the electricity mix within a PCA can fluctuate hourly depending on balancing measures, these intra-annual variations will not significantly impact our annual-level results. While it is infeasible to determine the precise amount of electricity each power plant provides to each data center, water utility, and wastewater treatment plant, our approach will enable us to estimate where each facility is most likely to draw its electricity. The dependency of a data center on local and imported electricity from other PCAs was calculated using equations (3) and (4).

$$DC\_E_{p,l} = DC\_E_p \times \left(1 - \sum_i r_i\right). \tag{3}$$

$$DC\_E_{p,im} = DC\_E_p \times \sum_i r_i \tag{4}$$

where $DC\_E_{p,l}$ and $DC\_E_{p,i}$ are the local (l) and imported (im) electricity (MWh) to a data center from PCA p, respectively. DC_E_p is the total electricity consumption of the data center, whereas r_i represents the electricity contribution of each PCA i to PCA p as follows:

$$r_i = \begin{cases} \dfrac{Import_{con}}{Generation_p + \sum Import_p - \sum Export_p}, & \text{if PCA } p \text{ is net importer} \\ 0, & \text{if PCA } p \text{ is net exporter} \end{cases}$$

where $Import_{con}$ is defined as the electricity from a linked PCA i that was consumed within PCA p. Any imported electricity not consumed with PCA p is re-exported.

Adjusted electricity consumption from the PCAs were assigned to the power plants using equation (5).

$$DC\_E_{p,k} = DC\_E_{p,adj} \times \frac{PP_k}{\sum_{k=1}^{n} PP_k} \tag{5}$$

where $DC\_E_{p,k}$ is the total energy directly consumed [MWh/y] by data centers from power plant k that is attributed to PCA p, $DC\_E_{p,adj}$ is the total electricity consumption of the data center from PCA p after adjusting for the inter-PCA electricity transfers, PP_k is the net generation by a specific power plant in MWh/y, and n is the number of power plants within PCA p. A similar approach was taken to connect power plants to water and wastewater utilities, with their electricity usage (and associated environmental footprints) then linked to the data center they service. Boiler feed pumps require an insignificant amount of electricity to provide water to power plants. Therefore, we truncate our analysis at this point.

2.3. Water consumption and GHG emissions associated with data centers

The indirect water and carbon footprint of each data center consists of water consumption or GHG emissions associated with the generation of (i) electricity utilized during data center operation, (ii) electricity used by water treatment plants for treatment and supply of cooling water to data centers, and (iii) electricity used by wastewater treatment plants to treat the wastewater generated by a data center. The GHG emissions or water consumption of a power plant supplying electricity to a data center is attributed to the data center as follows:

$$DC\_IF_k = DC\_E_k \times F_k \tag{6}$$

where DC_IF_k is the indirect footprint (water or carbon) associated with electricity used during the operation of a data center from power plant k and DC_E_k is the total energy used [MWh/y] by a data center from power plant k (from equation (5)). When calculating the indirect water footprint, F_k is the water consumption per unit of electricity generated by power plant k in m^3 MWh^{-1}. When calculating the indirect carbon footprint, F_k is the GHG emitted per unit of generated electricity by power plant k (tons CO_2-eq MWh^{-1}).

Although the IPCC does not consider water treatment a notable emitter of GHGs [37], wastewater treatment plants are a major source of GHG emission [38, 39]. In 2017, total GHG gas emission from wastewater treatment plants was estimated to be 20 million metric tons, with a direct emission rate of 0.3 kg CO_2-eq/y per m^3 of wastewater treated [38, 39]. In absence of facility specific emission data, we have used the average emission rate for treating wastewater for all wastewater generated from data center operation [39]. No direct GHG emissions are assumed to be associated with data center operation at the facility [18].

The EPA Safe Drinking Water Information System contains information on the location, system type, and source of water for each public water and wastewater utility [40, 41]. We assumed the nearest non-transient water treatment plant and wastewater treatment plant services a data center's water demand and wastewater management, respectively. After calculating the water supply requirement of a data center (discussed later in this section), the electricity needed for treatment and distribution of cooling water can be calculated using the data from Pabi *et al* [13] (see table S2). Water and wastewater treatment plants were linked to power plants (as described previously) to estimate the indirect water footprint associated with electricity required to distribute and treat water and wastewater used by a data center. We then sum the water consumed by each power plant to directly or indirectly service a data center to determine the total indirect water footprint of that data center. The indirect water footprint associated with each power plant was also aggregated within watershed boundaries to determine which water sources each data center was reliant upon.

Direct water consumption of a data center can be estimated from the heat generation capacity of a data center [42], which is related to the amount of electricity used [43]. Estimates of data center specific electricity demand were multiplied by the typical water cooling requirement [1]—1.8 m^3 MWh^{-1}—to estimate the direct water footprint of each data center. The direct water consumption is assigned to the watershed where the water utility supplying the data center withdraws its water.

Data center wastewater is largely comprised of blowdown; that is, the portion of cooling water removed from circulation and replaced with freshwater to prevent excessive concentration of undesirable components [44]. We assume all data centers utilize potable water supplies and cycle this water until the concentration of dissolved solids is roughly five times the supplied water [44]. We calculate blowdown from data center cooling towers using the following commonly employed approach [45]:

$$R_{\text{Blowdown}} = \frac{1}{C-1} \times R_{\text{Evaporation}} \tag{7}$$

where R_{Blowdown} is the blowdown rate required for a cooling tower (m^3 MWh^{-1}), C is the cycle of concentration for dissolved solids (assumed here as 5), and $R_{\text{Evaporation}}$ is the rate of evaporation (m^3 MWh^{-1}).

2.4. Water scarcity footprint

The water scarcity footprint (*WSF*; as defined by ISO 14046 and Boulay *et al* [46]) indicates the pressure exerted by consumptive water use on available freshwater within a river basin and determines the potential to deprive other societal and environmental water users from meeting their water demands. We quantified the *WSF* of data centers using the AWARE method set forth by Boulay *et al* [46] (see the Supportive Information for more details). Other societal and environmental water use data, as well as data on natural water availability within each US watershed, come from [47–49].

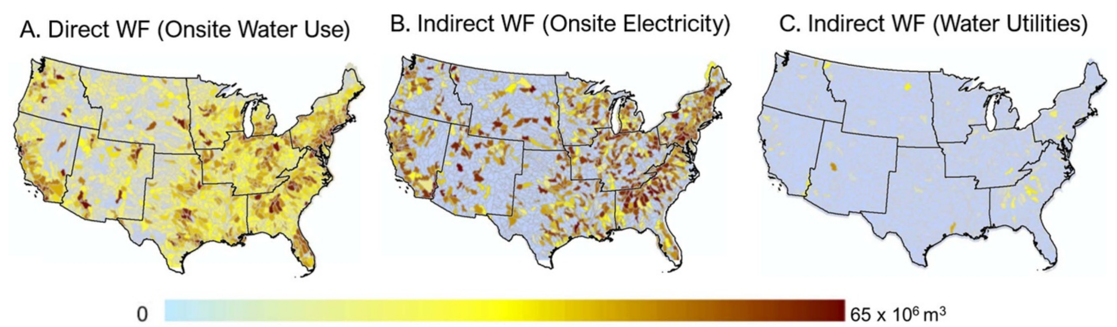

Figure 2. The blue water footprint (m^3) of US data centers in 2018, resolved to each subbasin (8-digit Hydrologic Unit Code). (A) Direct water footprint of data centers, (B) indirect water footprints associated with electricity utilization by data center equipment, and (C) indirect water footprints associated with treatment of supplied cooling water and treatment of generated wastewater.

3. Results

3.1. The water footprint of data centers

The total annual operational water footprint of US data centers in 2018 is estimated at 5.13×10^8 m^3. Data center water consumption is comprised of three components: (i) water consumed directly by the data center for cooling and other purposes (figure 2(A)), (ii) water consumed indirectly through electricity generation (figure 2(B)), and (iii) water consumed indirectly via the water embedded with the electricity consumption of water and wastewater utilities servicing the data center (figure 2(C)). The data center industry directly or indirectly draws water from 90% of US watersheds, as shown in figure 3(A).

Roughly three-fourths of US data centers' operational water footprint is from indirect water dependencies. The indirect water footprint of data centers in 2018 due to their electricity demands is 3.83×10^8 m^3, while the indirect water footprint attributed to water and wastewater utilities serving data centers is several orders of magnitude smaller (4.50×10^5 m^3). Nationally, we estimate that 1 MWh of energy consumption by a data center requires 7.1 m^3 of water. However, this national average masks the large spatial variation (range 1.8–105.9 m^3) in water demand associated with a data center's energy consumption. Data centers are indirectly dependent on water from every state in the contiguous US, much of which is sourced from power plants drawing water from subbasins in the eastern and western coastal states. Less than one-fifth of the industry's total electricity demand is from data centers in the West and Southwest US (regions as defined by NOAA [50]; see outlined areas in figures 2–5, and figure S4 for region identification), yet nearly one-third of the industry's indirect water footprint is attributed to data centers in these regions. Indirect water consumption associated with energy production in Southwest subbasins is particularly high, despite relatively low electricity supplied from this region, due to the disproportionate amount of electricity from water-intensive hydroelectricity facilities and the high evaporative potential in this arid region. Conversely, the Southeastern region consumes one-quarter of the electricity used by the industry but only one-fifth of the indirect water since data centers in this region source their electricity from less water-intensive sources.

On-site, direct water consumption of US data centers in 2018 is estimated at 1.30×10^8 m^3. Collectively, data centers are among the top-ten water consuming industrial or commercial industries in the US [47]. Approximately 1.70×10^7 m^3 of water directly consumed by data centers are sourced from a different subbasin than the location of the installed servers. Large direct water consumption in the Northeast, Southeast, and Southwest regions indicate clustering of servers in these regions. Combined direct and indirect water and carbon intensities are broken down by data center type in table 1.

3.2. Reliance of data centers on scarce water supplies

The WSF of data centers in 2018 is 1.29×10^9 m^3 of US equivalent water consumption, which is more than twice that of the volumetric water footprint reported in the previous section. The WSF (including both direct and indirect water requirements) per unit of energy consumption is 17.9 m^3 US-eq water MWh^{-1}, more than double the nationally averaged water intensity (7.1 m^3 MWh^{-1}) that does not account for water scarcity. WSFs that are larger than volumetric water footprints suggest that data centers disproportionately utilize water resources from watersheds experiencing greater water scarcity than average.

Only one-fourth of the volumetric water footprint of data centers resulted from onsite water use. Yet, more than 40% of the WSF is attributed to direct water consumption. This indicates that direct water consumption of data centers, which occurs close to where the data center is located, is skewed toward water stressed subbasins compared to its indirect water consumption, which is distributed

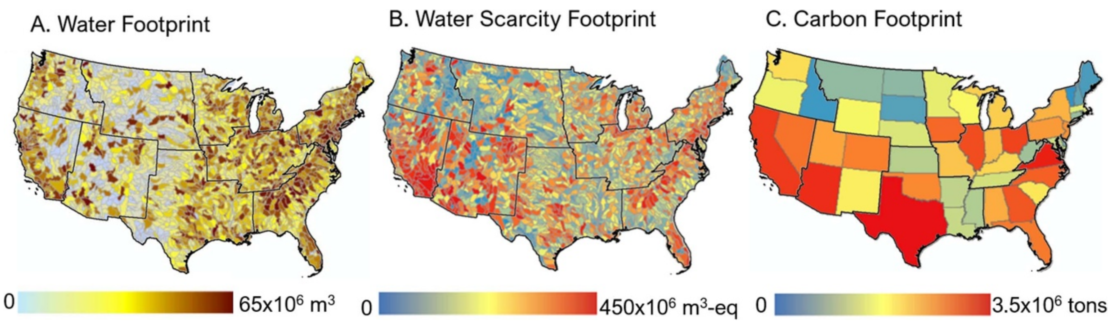

Figure 3. The subbasin or state of direct and indirect environmental impact associated with data center operation. (A) Water footprint (m^3). (B) WSF (m^3 US-eq water). (C) Carbon footprint (tons CO_2-eq/y).

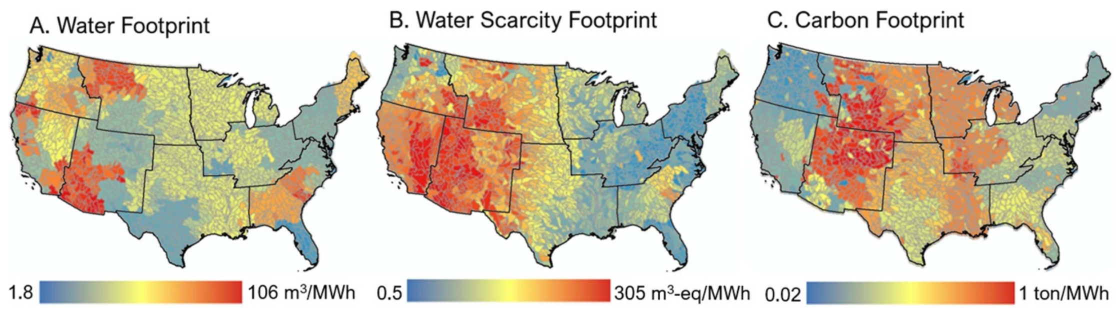

Figure 4. A data center's environmental footprint is highly contingent on where it is located. The (A) water intensity (m^3 MWh^{-1}), (B) water scarcity intensity (m^3 US-eq MWh^{-1}), and (C) GHG emissions intensity (tons CO_2-eq MWh^{-1}) of a hypothetical 1 MW data center placed in each of the 2110 subbasins of the continental United States.

more broadly geographically. We find that most of the watersheds that data centers draw from, particularly those in the Eastern US, face little to no water stress on average. In contrast, many of the watersheds in the Western US exhibit high levels of water stress, which is exacerbated by data centers direct and indirect water demands. Combined, the West and Southwestern watersheds supply only 20% of direct water and and 30% indirect water to data centers, while hosting approximately 20% of the nation's servers. Yet, 70% of the overall WSF occurs in these two regions (figure 3(B)), which indicates a disproportionate dependency on scarce waters in the western US.

3.3. GHG emissions attributed to data centers

Total GHG emissions attributed to data centers in 2018 was 3.15×10^7 tons CO_2-eq, which is almost 0.5% of total GHG emissions in the US [10]. A little over half (52%) of the total emissions of data center operations are attributed to the Northeast, Southeast, and Central US, which have a high concentration of thermoelectric power plants, along with large number of data centers (figure 3(C)). Almost 30% of the data center industry's emissions occur within the Central US, which relies heavily on coal and natural gas to meet its electricity demand. Yet, only 10% the industry's energy demand comes from the Central US, and just 9% of the water consumption associated with data centers operation occurs in this region. Moreover, the Central region is a net exporter of electricity to other regions, providing electricity for data centers located in the Northeast and Southeast regions, which houses almost one-third of servers. Yet, the generation of less carbon intensive electricity in the Northeast (hydroelectricity) and Southeast (wind/solar) regions means that while their electricity consumption comprises 34% of data centers' national electricity demand, these regions only constitute 23% of the industry's GHG emissions. The GHG emissions from treating the wastewater generated from data centers is around 550 tons/y (0.002% of total GHG emissions associated with data centers).

3.4. Where to locate data centers to minimize water and carbon footprints

Our results indicate significant variability of environmental impacts depending on where a data center is located. Here we explore how the geographic placement of a data center can lead to improved environmental outcomes. We find that the total water intensity of a data center can range from 1.8–106 m^3 MWh^{-1}, the water scarcity intensity from 0.5 to 305 m^3 US-eq MWh^{-1}, and the carbon intensity from 0.02 to 1 ton CO_2-eq MWh^{-1} depending on where the data center is placed (figure 4). Data center placement decisions are complicated by

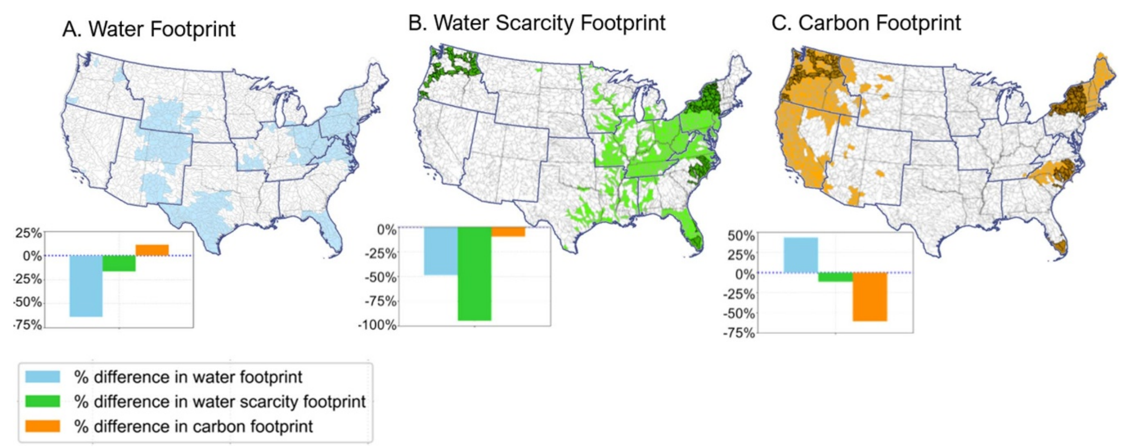

Figure 5. The (A) water footprint, (B) WSF, and (C) carbon footprint of data centers can be reduced by placing them in subbasins with the smallest footprint (top quartile of all subbasins), as denoted by the shaded subbasins in each panel. The bar graphs represent the percent reduction/increase of each environmental footprint within the shaded subbains compared to the national average data center environmental footprint. Hatched areas indicate subbasin that are among the most (top quartile) environmentally favorable locations for both water scarcity and GHG emissions.

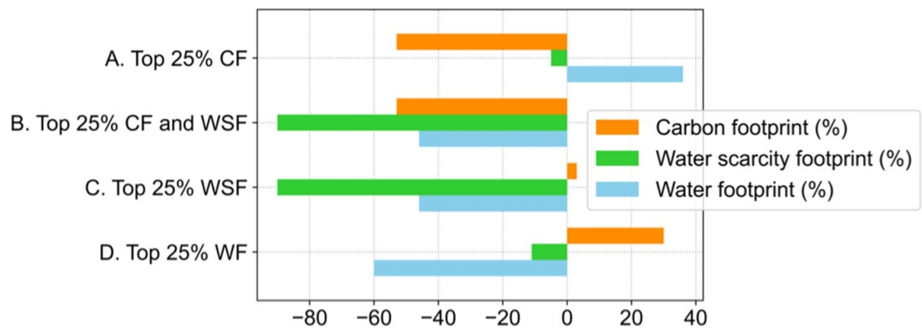

Figure 6. Percent change in environmental footprints associated with new data center servers compared to the 'business-as-usual' scenario. While the business-as-usual scenario assumes new servers will be placed in proportion to historical server locations, alternative scenarios explicitly consider the environmental implications of data center placement. Scenario A places data center servers in subbasins within the top quartile of all subbasins in environmental performance for both carbon (CF) and water scarcity (WSF) footprints. Scenario B represents server placement within subbasins in the top quartile for carbon footprints, while scenario C and D represent the best (top 25%) subbasins to place data center servers with respect to minimizing WSFs and water footprints (WF), respectively.

the electricity grid, which displaces environmental impacts from the physical location of a data center.

Figure 5 depicts subbasins in the top quartile of environmental performance as it relates to water footprint (5(A)), WSF (5(B)), and carbon footprint (5(C)) per MWh of electricity used by a hypothetical data center located within each subbasin. Less than 5% of subbasins are in the top quartile of environmental performance for both WSF and carbon footprint (hatched areas in figures 5(B) and (C), meaning that 40% of subbasins will require making a trade-off between reducing WSFs and carbon footprints. The remaining 55% of subbasins (white areas shared by figures 5(B) and (C) are not among the best locations to place a data center for either water or GHG reduction. Though the water footprint and WSF are related concepts, we show that nearly one-fifth of subbasins that were in the top quartile with respect to the water footprint are in the bottom quartile for WSF. In other words, a data center placed in these basins would use less water than 75% of potential sites, but it would draw that water from subbasins facing higher levels of water scarcity. In general, locating a data center within the Northeast, Northwest, and Southwest will reduce the facilities carbon footprint, while locating a data center in the Midwest and portions of the Southeast, Northeast, and Northwest will reduce its WSF.

In the coming years, cloud and hyperscale data centers will replace many smaller data centers [3]. This shift will lower the environmental footprint in some instances but introduce new environmental stress in other areas. Assuming added servers employ similar technology as existing servers and are placed in cloud and hyperscale data centers in proportion to the current spatial distribution of data centers (i.e. business-as-usual scenario), these new data center servers will have a collective water footprint of 77.77 $\times 10^6$ m^3 (15% of the current industry total), WSF of 170.56 $\times 10^6$ m^3 US-eq (9%), and 4.36 $\times 10^6$ tons CO_2-eq (14%). However, if these new servers are strategically placed in areas identified to have a lower environmental footprint, their water and carbon burden could be significantly reduced.

The WSF and carbon footprint of new data centers can be reduced by 153.00×10^6 m^3 US-eq (90% less than business-as-usual expansion) and 2.34×10^6 tons CO_2-eq (55%), respectively (figure 6(A)) if they are placed in areas with the lowest carbon and WSFs (hatched areas in figure 5). However, placing all new data centers within a small area may strain local energy and water infrastructure due to their collective water and energy demands. Data centers can be dispersed more broadly in areas that are favorable with respect to water footprint (figure 5(A)), WSF (figure 5(B)), or carbon footprint (figure 5(C)). However, only considering one environmental characteristic can lead to environmental trade-offs (figure 6).

4. Discussion and conclusion

The amount of data created and stored globally is expected to reach 175 Zettabytes by 2025, representing nearly a six-fold increase from 2018 [51]. The role of data centers in storing, managing, and distributing data has remained largely out of view of those dependent on their services. Similarly, the environmental implications of data centers have been obscured from public view. Here, for the first time, we estimate the water and carbon footprints of the US data center industry using infrastructure and facility-level data. Data centers heavy reliance on water scarce basins to supply their direct and indirect water requirements not only highlight the industry's role in local water scarcity, but also exposes potential risk since water stress is expected to increase in many watersheds due to increases in water demands and more intense, prolonged droughts due to climate change [52–54]. For these reasons, environmental considerations may warrant attention alongside typical infrastructure, regulatory, workforce, customer-/client proximity, economic, and tax considerations when locating new data centers.

The data center industry can take several measures to reduce its environmental footprint, as well as minimize its water scarcity risks. First, the industry can continue its energy efficiency improvements. The ongoing shift to more efficient hyperscale and colocation data centers will lower the energy requirements per compute instance. Software and hardware advances, as well as further PUE improvements, can continue to reduce energy requirements, and thus environmental externalities. For instance, quarterly PUE of as low as 1.07 has been reported by Google for some of their data centers [55]. Liquid immersion cooling technologies show promise of further reductions in PUE, with one study reporting a PUE below 1.04 [56]. The prospect of recovering low-grade heat (i.e. low temperature or unstable source of heat) from data centers for space or water heating is limited; however, approaches such as absorption cooling and organic Rankine cycle are promising technologies for generating electricity from waste heat [57].

Second, the data center industry can make investments in solar and wind energy. Directly connecting data center facilities to wind and solar energy sources ensures that water and carbon footprints are minimized. Purchasing renewable energy certificates from electricity providers does not necessarily reduce the water or carbon footprints of a data center. However, these investments gradually shift the electrical grid toward renewable energy sources, thus lowering the overall environmental impact of all energy users. Data center workloads can be migrated between data centers to align with the portion of the grid where renewable electricity supplies exceed instantaneous demand [58].

Third, as we show in this study, strategically locating new data centers can significantly reduce their environmental footprint. Climatic factors can make some areas more favorable due to lower ambient temperatures, thereby reducing cooling requirements. Lower cooling requirements reduces both direct and indirect water consumption, as well as GHG emissions, associated with data center operation. Since most data centers meet their electricity demands from the grid, the composition of power plants supplying electricity to a data center plays a significant role in a data center's environmental footprint. For an industry that is centered on technological innovation, we show that real estate decisions may play a similar role as technological advances in reducing the environmental footprint of data centers.

Data availability statement

Data center locations come from [4, 19–21]. Power plant electricity generation, water consumption, and GHG emission data come from [35, 59, 60]. Location of public water utility and wastewater treatment data comes from [40, 41]. Study data and code can be found in the Supporting Information, as well as at https://doi.org/10.7294/14504913. The DOI contains relevant shapefiles, tabular data, and scripts to help replicate and extend our work. All data that support the findings of this study are included within the article (and any supplementary files).

Acknowledgments

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Author contributions

L M conceived and designed the study. M A B S conducted the analysis. A S provided data and fundamental concepts regarding the analysis. All authors contributed to the writing of the manuscript.

Conflict of interest

The authors declare that they have no competing financial interests.

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DOCKETED

Docket Number:	19-SPPE-04
Project Title:	SJ2
TN #:	240942
Document Title:	SJC Data Center City of San Jose Form 327 Natural Gas Exception Request
Description:	N/A
Filer:	Jerry Salamy
Organization:	Jacobs
Submitter Role:	Applicant Consultant
Submission Date:	12/15/2021 1:20:44 PM
Docketed Date:	12/15/2021

NATURAL GAS PROHIBITION EXEMPTION FORM

The City's updated Natural Gas Ban goes into effect on August 1, 2021, as outlined in Municipal Code CHAPTER 17.845 - Prohibition of Natural Gas Infrastructure in Newly Constructed Buildings. Natural Gas Infrastructure shall be prohibited in Newly Constructed Buildings that are wholly or partly located in the City of San Jose, with allowance for exceptions and exemptions, as summarized below (please read the ordinance for full language).

EXCEPTIONS & EXEMPTIONS

Hospitals and Certain Attached ADUs are Excepted. These requirements do not apply to Hospitals, as defined in the California Building Code, Chapter 2, Section 202. (17.845.020(G)) Attached accessory dwelling units (ADUs**)** that are proposed in an existing mixed-fuel building are also excepted.

Distributed Energy Resource Facilities may be Excepted - Facilities with a Distributed Energy Resource (DER) for necessary operations to protect the public health, safety, or economic welfare in the event of an electric grid outage may apply for an exception on or before December 31, 2022 as allowed by the criteria of the Municipal Code 17.845.040.

Manufacturing/Industrial Facilities and Food Service Establishments - There are limited exemptions for Manufacturing and Industrial Facilities and Food Service Establishments. Exemptions may be applied for on or before December 31, 2022 as allowed by the criteria of the Municipal Code 17.845.045. The limited exemption may be approved by the Director of Planning, Building, Code Enforcement or his or her designee. The Director may issue a decision requiring compliance with less than the full extent of the requirements of the Chapter, but to the fullest extent reasonably achievable given the circumstances, provided:

- The non-exempt areas of the project comply with the code provisions.
- The proposed design meets or exceed the electrification readiness requirements in Municipal Code 24.12.

Hardship Exemption (section 17.845.050). The City allows for hardship exemptions that meet the criteria outlined in the Municipal Code 17.845.050. The hardship exemption may be approved by the Director of Planning, Building, Code Enforcement, or his or her designee. The Director may issue a decision requiring compliance with less than the full extent of the requirements of the Chapter, but to the fullest extent reasonably achievable given the circumstances, provided:

- The non-exempt areas of the project comply with the code provisions.
- The proposed design meets or exceed the electrification readiness requirements in Municipal Code 24.12.

This form enables application of an exemption. For information more information about the ban and Reach Code, please visit the San Jose Reach Code webpage and view the FAQs.

INSTRUCTIONS

Complete and submit this form to apply for an exemption.

HOW TO SUBMIT

- This form should be submitted with your building permit application. Schedule your required appointment for your building permit project at www.sanjoseca.gov/BuildingPermitServices.
- Please ensure that you sign and save all forms and documents as PDF files.

This is a computer-fillable PDF form and signatures, if required, must be a Digital ID Signature.
Follow instructions for Digital Forms & Signatures.

Staff will assign PLAN CHECK #:

1. PROPERTY INFORMATION

FIND APN: WWW.SCCASSESSOR.ORG. FIND COUNCIL DISTRICT AND PERMIT INFO: WWW.SJPERMITS.ORG

PROJECT NAME: San José City Data Center

PROJECT ADDRESS/ES: 1657 Alviso-Milpitas Road, San Jose

2. TYPE OF EXEMPTION/EXCEPTION

2.a. Check the type of exemption (or excepton for DER) that is applicable to your project:

☑ **Distributed Energy Resource (DER) Facility,** requesting exception for necessary operations to protect the public health, safety, or economic welfare in the event of an electric grid outage.

☐ **Manufacturing and Industrial Facility**, requesting limited exemption for the area with Process Loads. If checking this box, please also be sure to include information in Section 3:

☐ **Food Service Establishment,** requesting limited exemption for area with Cooking Equipment or Commercial Kitchen.

☐ **Hardship Exemption** - The type of project, site conditions, or operational requirements make it infeasible or a hardship to meet the requirements.

2.b. In the space below, briefly describe the area that is the subject of the limited exemption (or DER exception) and justify the request. Attach typed pages to the form if more space is needed.

Please see Attachment 1 - San José City Data Center (SP19-066) Distributed Energy Resource (DER) Facility Exception Request

3. FACILITIES WITH A DISTRIBUTED ENERGY RESOURCE SYSTEM

Please provide the following information for your DER system:

SYSTEM SIZE (kW): 96000	UNIT EFFICIENCY (KWH/THERM):

ESTIMATED TOTAL ANNUAL GENERATION (KWH): 19,051,200 (450 kW * 224 Units * 189 hr)

ESTIMATED ANNUAL FUEL USAGE BY FUEL TYPE: 234,349 MMBtu/Year

EMISSION FACTORS (CO_2/KWH, CH_4/KWH, N_2O/KWH) IF AVAILABLE: CO_2 - 56.06, CH_4 - 0.001, N_2O - 0.0001 kg/MMBtu

4. SIGNATURE & CONTACT INFORMATION

This exemption application is requested by:

Sieu Quan Digitally signed by Sieu Quan
DN: C=US, E=sieuquan@microsoft.com, O=Microsoft, OU=Datacenter Engineering, CN=Sieu Quan
Reason: I am approving this document
Date: 2021.12.14 12:24:42-08'00'

12/14/2021

• SIGNATURE of Property Owner DATE: [MM/DD/YYYY]

PRINT NAME: Sieu Quan

TITLE IF APPLICABLE: Design Manager, AMER West Region

FIRM NAME IF APPLICABLE: Microsoft, Inc.

EMAIL: sieu.quan@microsoft.com PHONE: 425.538.6254

MAILING ADDRESS: 5600 148th Ave NE Redmond, WA 98052

PERSON TO CONTACT WITH DECISION IF DIFFERENT FROM ABOVE:

NAME: Jerry Salamy

EMAIL: Jerry.Salamy@jacobs.com

A Digital ID Signature is required of the property owner or legally authorized agent of the property owner. By signing this application, you acknowledge that you are the property owner or the legally authorized agent of the property owner. For signatures by multiple property owners, use the Affidavit Of Ownership-Multiple Owners Form.

DISCLAIMER: Applicants must recognize that approval of the exemption is based on the documentation provided at the time of approval. If during the review or inspection process, a City building official notices deviations from the original application, the approval becomes null and void. The applicant will then need to either revert to the original proposal or file a new application based on revised plans. For proposals that are processed prior to submittal of a full set of plans, only a conceptual approval can be given; a valid approval to proceed with the proposal requires submittal of all construction documents.

OFFICE USE ONLY

FINDINGS:

BUILDING INSPECTION MANAGER Signature:	☐ RECOMMENDED	☐ NOT RECOMMENDED
CHIEF BUILDING OFFICIAL Signature:	☐ APPROVED	☐ DENIED
DEPARTMENT DIRECTOR or Designee Signature:	☐ APPROVED	☐ DENIED

San José City Data Center (SP19-066)

Distributed Energy Resource (DER) Facility Exception Request

San José Municipal Code Section 17.845.030 B.

Natural Gas Infrastructure shall not be extended to any system or device within a building for which an equivalent all-electric system or design is available.

San José Municipal Code Section 17.845.040 B. - DER Exception

The requirements of this Chapter shall not apply to [a] facilities with a physical connection to the electrical grid and a Distributed Energy Resource for necessary operational requirements to protect the public health, safety, or economic welfare in the event of an electric grid outage…

Justification for DER Exception

The San José City Data Center (SJC) is critical infrastructure designed to support data storage and processing needs and to facilitate communication via internet connections, without interruption, both daily and during public emergencies. Crucial public emergency services such as 911, Offices of Emergency Management, police, fire, and utilities infrastructure rely on data centers for their continuous operation, as do government agencies dealing with critical health, safety, and economic welfare issues. Private enterprises such as hospitals, nursing and rehabilitation facilities, private security companies, financial institutions and others also rely on data centers for continuous operation.

The selected backup electric generation technology for data centers must be extremely reliable in the event of Pacific Gas & Electric Company (PG&E) electrical power outages. Such critical infrastructure resiliency is necessary to protect the health, safety, and economic welfare of the public in the event of an electrical power grid outage in the region. For the SJC the applicant is proposing the use of natural gas for its backup electric generation for both reliability and environmental benefits. The use of natural gas will allow the backup generating facility to further protect the health, safety and economic welfare of the public at times when the electric grid is strained by allowing PG&E to divert electric service from the data center to other critical and residential uses.

The backup generating facility will, therefore, provide DER support in two critical ways, both of which will protect the health, safety and economic welfare of the public: 1) ensuring the critical data center functions are maintained for public use during a PG&E outage at the data center; and 2) providing a tool for PG&E to redirect electricity to other critical uses to avoid outages at locations other than the data center.

Equivalent All-electric System or Design – Not Available

The natural gas generators proposed for SJC do not have an equivalent all-electric system or design available. The primary purpose of the natural gas generators is to provide electrical power to SJC in the event that PG&E is unable to provide electrical power to the facility's onsite substation.

No all-electric system or design can reliably replace the natural gas generators given the limited size of the project site. Gas-fired generators can provide backup power for an extensive period of time. Backup generation using batteries would require an extensive amount of space to supply adequate backup capacity. In the Great Oaks South Backup Generating Facility Environmental Impact Report (GO EIR), the California Energy Commission (CEC) estimated that approximately 6 acres would be required to supply 99 MW of uninterruptable power for 41 hours of grid outage.[1] This additional acreage is not available at the SJC site. In addition, the density of the batteries would increase fire risk and result in other attendant design, safety, and maintenance issues to reduce the risk to an acceptable level. The GO EIR also concluded that biodiesel and fuel cell technology are likewise unsuitable as alternative technologies, based on their infeasibility and/or lack of a sufficient level of proven reliability required for the critical infrastructure.[2] Where a site has two independent back-up natural gas sources, the GO EIR concluded that the most reliable design option is natural gas.

Here, the SJC project site is supported by two (2) natural gas connections from separate sources, currently located immediately adjacent to the site in Alviso-Milpitas Road. The onsite natural gas infrastructure would be designed to meet required seismic standards providing a low probability of operational failure.

Environmentally Superior Alternative

The Applicant expects the California Energy Commission to issue a draft EIR for the SJC Project on December 23, 2021. The draft EIR is expected to conclude that the SJC Project does not have a significant, unmitigated environmental impact, including air quality, energy resources, and greenhouse gases.

The GO EIR found the use of natural gas internal combustion engines to be the environmentally superior alternative for the Great Oaks data center due to its significant reductions in criteria air pollutants. The GO EIR analyzed criteria pollutant emissions and carbon dioxide emissions of natural gas engines against emissions from petroleum diesel fired engines. The EIR concluded that oxides of nitrogen and volatile organic compound emissions would be reduced by more than 99 percent using natural gas internal combustion engines compared to diesel engines that meet Tier 2 or Tier 4 emission standards. The PM emissions would be reduced by more than 95 percent using natural gas compared to diesel engines that meet Tier 4 emission standards, there would be an 86 percent reduction in carbon monoxide emissions, and a 56 percent reduction in sulfur dioxide emissions. The GO EIR also determined that natural gas would reduce greenhouse gas (GHG) emissions by approximately 10 percent compared to Tier 1 and Tier 4 diesel engines. When extending to the full fuel cycle, GHG emissions from natural gas engines fueled with natural gas produced from fossil feedstocks would be 20 percent lower than those from

[1] Great Oaks South Backup Generating Facility Environmental Impact Report (GO EIR), State Clearinghouse # 2020100431, California Energy Commission, 5/21/2021
[2] See fn 1.

petroleum diesel. As an added benefit, the SJC Applicant has committed to using renewable natural gas for the project. It is important to California's goals to replace fossil-derived natural gas with renewable natural gas to have large users make this commitment.

Distributed Energy Resource Exception

City Municipal Code Section 17.845.020 E defines "distributed energy resource" as *an electric generation or storage technology that complies with the emissions standards adopted by the State Air Resources Board pursuant to the distributed generation certification requirements of Section 94203 of Title 17 of the California Code of Regulations, or any successor regulation.*

Section 94203 of Title 17 of the California Code of Regulations requires that after January 1, 2007, fossil fueled distributed generation units meet specific emission limits of 0.07 pounds of Oxides of Nitrogen per megawatt-hour, 0.10 pounds of carbon monoxide per megawatt-hour, and 0.02 pounds of volatile organic compounds per megawatt-hour.

Section 94202 of Title 17 of the California Code of Regulations defines "distributed generation" as *electrical generation technologies that produce electricity near the place of use.*

Section 94202 of Title 17 further defines "generation technology" as *reciprocating engines, external combustion engines, combustion turbines, photovoltaics, wind turbines, fuel cells or any combination thereof.*

Distributed Energy Resource

Using natural gas for the SJC back-up distributed energy resource will enable the Applicant to participate in PG&E's Base Interruptible Program (BIP). This program was designed to reduce electrical loads on PG&E's system when the California Independent System Operator (CAISO) issues a curtailment notice. The SJC project is *physically connected* to PG&E's electrical grid with two redundant electrical power connections from the SJC onsite substation to the adjacent PG&E Los Esteros Substation. Participating in PG&E's BIP program will enable SJC to reduce its power load by disconnecting the project from the electrical grid and self-generating the required electric load through the natural gas generators, making a significant quantity of electric power available to PG&E's grid during CAISO curtailment events. This ability to make additional power available for distribution to the power grid during emergencies and critical events will assist PG&E in protecting the public health, safety, or economic welfare of the region enabling PG&E to redirect the electricity from the data center to other critical facilities and residential uses. In other words, the backup generating facility will act as a distributed resource to protect the data center during outages and will operate as a grid distributed resource for PG&E to prevent outages and curtailment for other users. The dual purpose of the backup generating facility, when balanced against the infeasibility of non-combustion alternatives, necessitates the use of natural gas.

Fossil Fueled Distributed Generation Units Emission Limits

The Applicant has provided documentation (see Attachment 2) confirming that the proposed natural gas generators comply with Section 94203 of Title 17 of the California Code of

Regulations fossil fueled distributed generation unit emission limits of 0.07 pounds of Oxides of Nitrogen per megawatt-hour, 0.10 pounds of carbon monoxide per megawatt-hour, and 0.02 pounds of volatile organic compounds per megawatt-hour. Therefore, the SJC project complies Section 17.845 of the City of San Jose Municipal Code.

Precedent

The GO EIR similarly concluded that natural gas internal combustion engines, by definition, are a Distributed Energy Resource, and that data centers have operational requirements to protect the critical services they provide. Thus, the use of natural gas engines for data center projects, such as the SJC project, falls under the DER exception.

Summary

By definition, the natural gas generators at SJC are a Distributed Energy Resource and fall under the DER exception to the San José Municipal Code Section 17.845.030 natural gas prohibition for new building construction. Data centers provide critical communication services that must be reliably maintained during public emergencies. There is no equivalent all-electric system or design currently available to provide the resiliency demanded by the system, as analyzed and determined previously for similar data center projects, as well as to provide the on-demand participation in PG&E's BIP program to avoid outages and curtailment elsewhere on the electric system.

Public health impacts using natural gas would be less than those that would occur with diesel engines. Air quality impacts using natural gas generators are expected to be much less than those that would occur with diesel engines. GHG impacts would also be less than those of diesel engines due to the reduced GHG emissions during the entire fuel cycle. There is a low probability of operational failure because the onsite natural gas infrastructure will be designed to meet required seismic standards. The redundancy of the two natural gas sources existing at the site boundary makes natural gas generators a reliable choice for SJC data center backup power.

The SJC project satisfies the intent and requirements of San Jose Municipal Code Section 17.845.040 and is considered a facility with a distributed energy resource.

Attachment 2: Enchanted Rock Emission Guarantee Letter

Enchanted Rock, LLC
1113 Vine Street, Suite # 101
Houston, TX 77002
713-429-4091 Phone
281-509-9559 Fax

July 21, 2021

Ms. Jordan Weiszhaar
Microsoft

Via email to jordanw@microsoft.com

Subject: Emission Limits — Enchanted Rock 21.9 L Natural Gas-fired Generator

Dear Ms. Weiszhaar:

Per your request, below are the guaranteed controlled emissions limits for Enchanted Rock's 21.9L natural gas fired generator with updated PM levels and the CARB DG certified emissions package we proposed.

Parameter	**lb/MW-hr**
Nitrogen Oxides (NOx)	0.070
Carbon Monoxide (CO)	0.100
Hydrocarbons (VOC)	0.020
Particulate Matter (PM10/PM2.5)	0.009

If you have any questions regarding the information presented above, please contact the undersigned via email at nsmith@enchantedrock.com.

Sincerely,

N. Smith

Norman Smith
EVP of Engineering

From: Salamy, Jerry/SAC
Sent: Wednesday, December 15, 2021 12:24 PM
To: julie.benabente@sanjoseca.gov
Cc: Amador, Lisa/LAC; Madams, Sarah; Petersen, Adam; Atienza, Manuel
Subject: SP19-066 DER Exception Form
Attachments: SJC0203_Form327NaturalGasProhibitionException_2021-12-14.pdf

Hi Julie,

Per our conversation with the CEC on November 17th, attached is the San José Building Department SJC Form 327 – Natural Gas Prohibition Exception for your consideration. Please let me know if you have any comments or questions.

Thanks,

Jerry Salamy | Jacobs | Project Manager
M:+916.769.8919 | jerry.salamy@jacobs.com
2485 Natomas Park Drive, Suite 600 | Sacramento, CA 95833 | USA

PTO December 23rd to January 3rd

Title VI and Environmental Justice

- Overview
- How are EJ and Title VI Different?
- Title VI
- Resources

Overview

"Simple justice requires that public funds, to which all taxpayers of all races [colors, and national origins] contribute, not be spent in any fashion which encourages, entrenches, subsidizes or results in racial [color or national origin] discrimination." — **President John F. Kennedy, 1963**

On February 11, 1994, Executive Order 12898 <https://www.archives.gov/federal-register/executive-orders/1994.html#12898> was issued to direct Federal agencies to incorporate achieving environmental justice into their mission. Accompanying that Executive Order was a Presidential Memorandum <https://epa.gov/environmentaljustice/presidential-memorandum-heads-all-departments-and-agencies-executive-order> stating, in part,

In accordance with Title VI of the Civil Rights Act of 1964, each Federal agency shall ensure that all programs or activities receiving Federal financial assistance that affect human health or the environment do not directly, or through contractual or other arrangements, use criteria, methods, or practices that discriminate on the basis of race, color, or national origin.

With that directive in mind, in August 2011 the Environmental Justice IWG established a Title VI Committee to address the intersection of agencies' environmental justice efforts with their Title VI enforcement and compliance responsibilities.

- Read the Presidential Memorandum to Executive Order on Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations <https://epa.gov/environmentaljustice/presidential-memorandum-heads-all-departments-and-agencies-executive-order>

How are EJ and Title VI Different?

Title VI of the Civil Rights Act prohibits recipients of federal financial assistance (states, grantees, etc.) from discriminating based on race, color, or national origin in any program or activity.

Executive Order 12898, on the other hand, directs federal agencies to identify and address, as appropriate, disproportionally high adverse human health and environmental effects of their programs, policies, and activities on minority populations and low-income populations.

However, a Title VI civil rights complaint may raise environmental justice issues when challenging a recipient's activity. For instance, if a state agency receives funds from EPA to run a clean air program, that state recipient is legally prohibited from discriminating on the basis of race, color or national origin under Title VI when engaging in clean air enforcement activities.

The EPA, in complying with Executive Order 12898, can also ensure the programs it funds consider disproportionately high adverse human health and environmental effects on minority and low income populations.

For more information of the differences and similarities, see the EJ and Title VI comparison chart <https://epa.gov/environmentaljustice/title-vi-and-executive-order-12898-comparison>.

Title VI

1. Title VI prohibits recipients of federal financial assistance (*e.g.*, states, universities, local governments) from discriminating on the basis of race, color, or national origin in their programs or activities.

2. Title VI is a federal law that applies to federal financial assistance recipients (*i.e.*, persons or entities that receive EPA financial assistance) and not to EPA itself as the Executive Order does.
3. Title VI allows persons to file administrative complaints with the federal departments and agencies that provide financial assistance alleging discrimination based on race, color, or national origin by recipients of federal funds.
4. Under Title VI, EPA has a responsibility to ensure that its funds are not being used to subsidize discrimination based on race, color, or national origin. This prohibition against discrimination under Title VI has been a statutory mandate since 1964 and EPA has had Title VI regulations since 1973.
5. EPA's Office of Civil Rights is responsible for the Agency's administration of Title VI, including investigation of such complaints.

Resources

- Links to agencies Offices of Civil Rights <https://www.justice.gov/crt/fcs/agency-ocr-offices>
- Limited English Proficiency: A Federal Interagency Website <http://www.lep.gov>
- Advancing Environmental Justice Through Title VI of the Civil Rights Act <https://epa.gov/environmentaljustice/plan-ej-2014-advancing-environmental-justice-through-title-vi-civil-rights-act>
- Understanding EPA's Nondiscrimination Statutes and Regulations <https://epa.gov/ocr/title-vi-laws-and-regulations>
- Executive Order 12250: Coordination of Grant-Related Civil Rights Statutes <https://www.justice.gov/crt/executive-order-12250>
- Executive Order 13166: Improving Access to Services for Persons with Limited English Proficiency <http://www.justice.gov/crt/about/cor/13166.php>
- Title VI Coordination Regulations <http://www.justice.gov/crt/about/cor/byagency/28cfr424.pdf>
- Title VI Enforcement Guidelines <http://www.justice.gov/crt/about/cor/byagency/28cfr503.pdf>
- Title VI Legal Manual <https://epa.gov/sites/production/files/2021-01/documents/titlevi_legal_manual_rev._ed_1.pdf>
- OMB Draft Assurance Language <http://www.justice.gov/crt/about/cor/draft_assurance_language.pdf>
- January 28. 1999 Block Grant Memo <http://www.justice.gov/crt/about/cor/pubs/blkgrnt.php>

- Recovery Act Non-Discrimination Notice <http://www.justice.gov/crt/about/cor/recoveryactnotice09.pdf>
- Your Rights under Title VI of the Civil Rights Act of 1964, brochure <http://www.justice.gov/crt/about/cor/pubs/titlevieng.pdf>

Environmental Justice (EJ) Home <https://epa.gov/environmentaljustice>

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National Environmental Justice Advisory Council <https://epa.gov/environmentaljustice/national-environmental-justice-advisory-council>

Grants and Resources <https://epa.gov/environmentaljustice/environmental-justice-grants-and-resources>

EJ in Your Community <https://epa.gov/environmentaljustice/environmental-justice-your-community>

Federal Interagency Working Group on EJ <https://epa.gov/environmentaljustice/federal-interagency-working-group-environmental-justice-ej-iwg>

EJ and National Environmental Policy Act <https://epa.gov/environmentaljustice/environmental-justice-and-national-environmental-policy-act>

EJ and Title VI

EJ for Tribes and Indigenous Peoples <https://epa.gov/environmentaljustice/environmental-justice-tribes-and-indigenous-peoples>

Equitable Development and EJ <https://epa.gov/environmentaljustice/equitable-development-and-environmental-justice>

Community Voices on EJ <https://epa.gov/environmentaljustice/community-voices-environmental-justice>

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