Energy Efficient VoIP systems

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Hi, I am Altanai

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Patent on “Multimedia Conferencing“

Author of the book - WebRTC Integrator's Guide

Skilled in CPaaS, carrier-grade WebRTC-SIP telecom platforms for Unified communication-collaboration, signalling gateways, SBC, soft turrets, IoT-surveillance and telecom integrations.

Currently pursuing MS Computer Science at Seattle University.

Energy Efficiency in RTC
Co2 footprint
- devices, transmission and DC
- Mesh
- Centralized

Peaks are harmful for Env
MCU is good for Env
- Battery storage + peak shaving
- Battery storage + renewables
- carbon aware call schedulers
- Media handover for energy efficiency

Abstract : Energy efficient and carbon footprint aware VoIP applications

With the sharp rise in WFM and remote learning, there has been a many fold increase in usage of VoIP, especially in WebRTC based video conferencing. This talk focuses on the impact of CPU performance on the carbon emission from the grid based electricity generation perspective. Measures such as BTM(Behind the meter storage) for ToU (Time of Use) billing, peak shaving algorithms and RTC optimizations that yield better energy savings.Experimental findings using Call traffic, CPU utilization on various RTP topologies and SIP/WebRTC call flow optimizations are presented.

It is inspired from my ongoing research on whether renewables and energy storage integration green the electric grid.

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Internet explosion

Is internet is becoming an environmental problem ?

footprint of an email also varies dramatically, from 0.3g CO2e for a spam email to 4g CO2e for a regular email and 50g CO2e for one with a photo or hefty attachment.

- BBC[25]

..Bitcoin currently consumes around 110 Terawatt Hours per year - 0.55% of global electricity production

- Harvard Business Review [12]

IEA estimate for one hour of streaming video in 2019 is 36 gCO2 - IEA [15]

1 hour of Netflix consumes 0.8 kWh - Netflix [18]

“Turn off that camera during virtual meetings “ article states that 1 hour of videoconferencing or streaming : - [14] multi university study

- emits 150 - 1,000 grams of carbon dioxide
- requires 2-12 liters of water
- demands a land area adding up to about the size of an iPad Mini.

… Google Meet (0.164 gEqCO 2), Tixeo (0.166 gEqCO 2) and Microsoft Teams (0.167 gEqCO 2) - [26] greenspector

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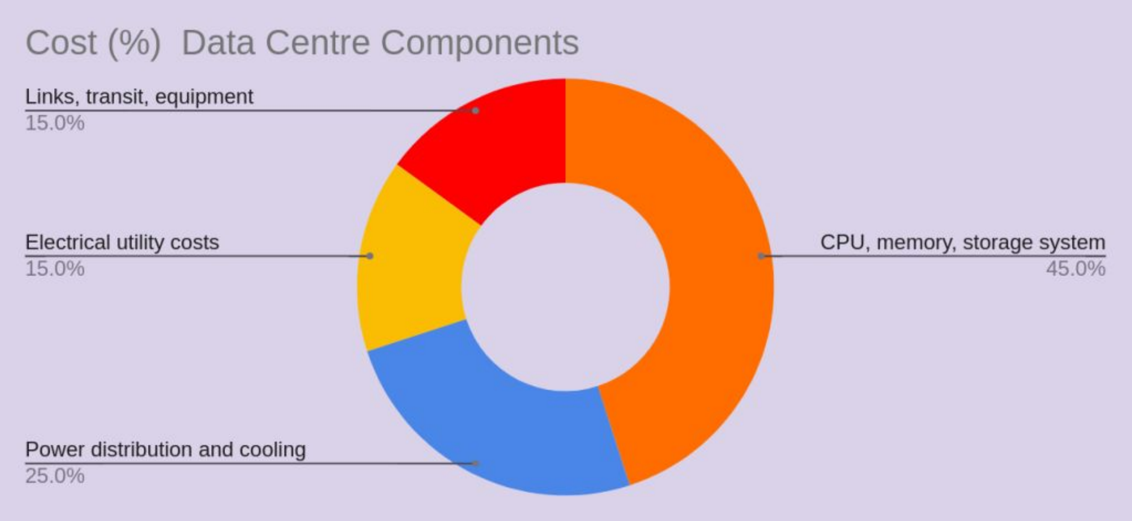
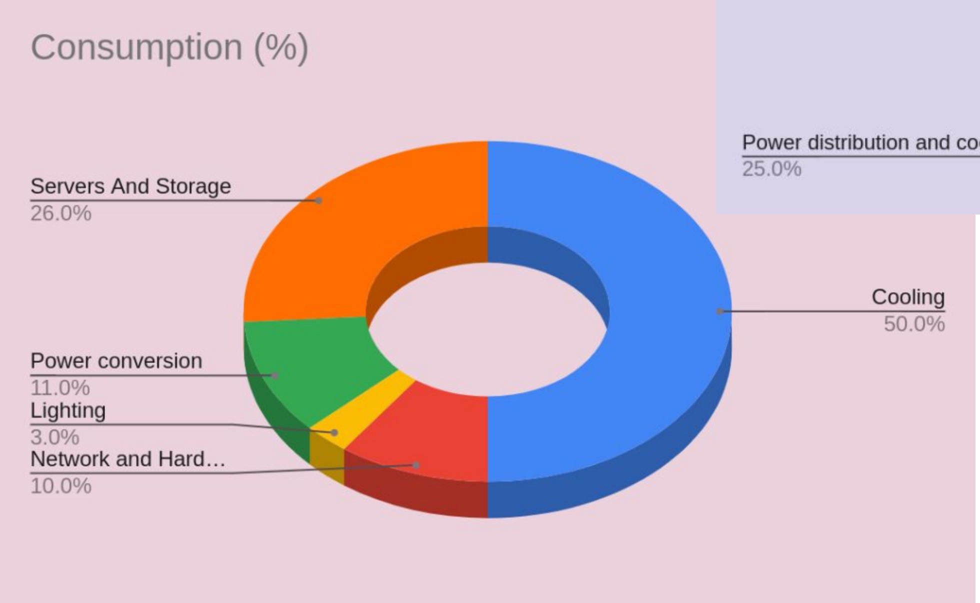
Data Centres Energy Efficiency





Some noteworthy innovations made in Data centre for energy efficiency :

1. PUE and star efficiency requirements
2. Optimizing the cooling systems and rack placements
3. Throttle-down drive

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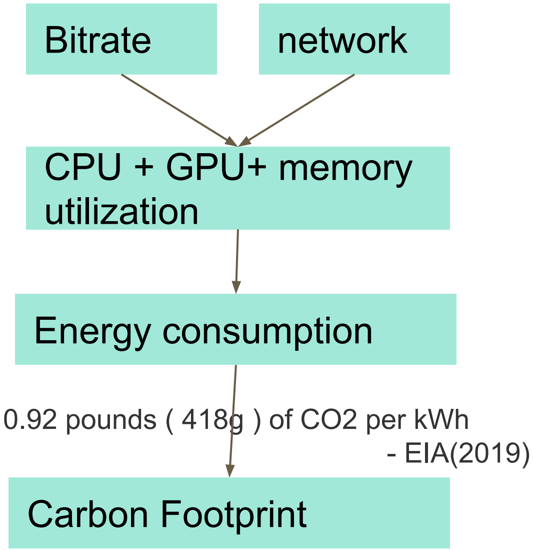
Bitrate, Energy Consumption and Carbon footprint



Audio Streaming

- 36 MB/hr or 0.036 GB/hr

Video + Audio streaming bitrate

- Mobile : 0.25 GB/hr
- SD Video Call : 0.7 GB/hr
- Streaming Video(480p) : 1.845 GB/hr
- HD 2K : 3GB/hr
- UHD/4K : 7 GB/hr

UHD carbon footprint is 441 g CO2e / hour (global median) *
Then streaming 4 hours a days in UHD for a month => (4 * 30 * 441) / 1000 = 52.92 = ~ 53 kg CO2e / month

Energy Consumption

- **Transmission** **0.018 KWh per viewing hour**
- **Devices** **0.022 KWh per viewing hour**

(EIA figure on Netflix video 2019 by George Kamiya, also depends on n/w , resolution , screen ..)

- **Server in DC per session ~0.06 KWh**

(calculated from compute intensive VMs , stressing CPU to 6700 calls at 80% utilization peaks 400 W [21] power consumption)

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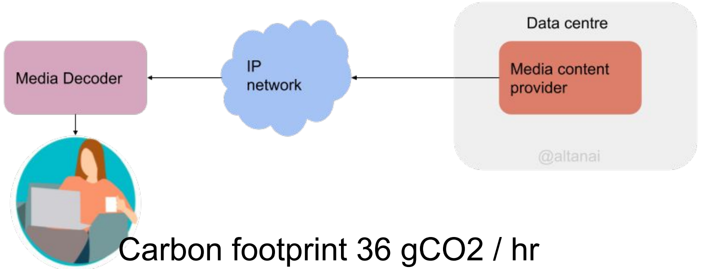
Share of streaming energy use from devices, data transmission and data centres

Laptop Wifi HD simplified usecase

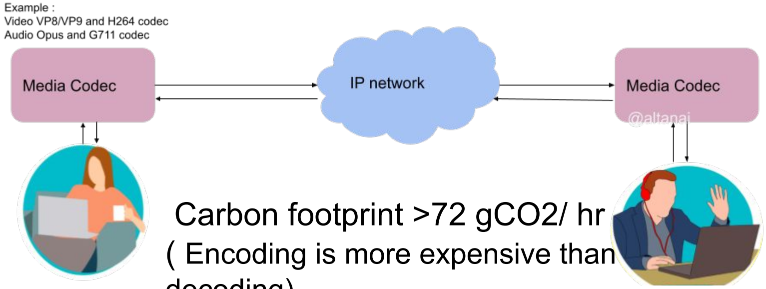
One way stream

Video On Demand

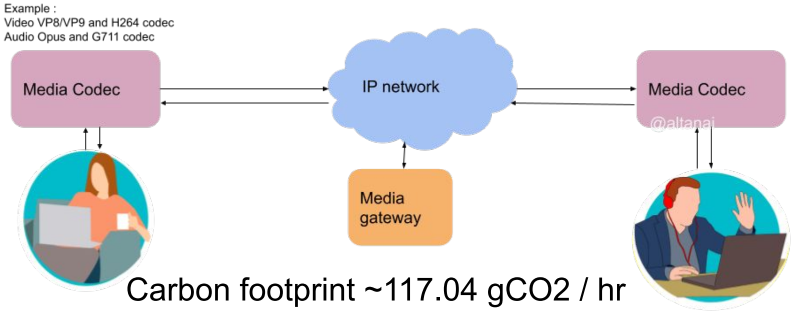


Carbon footprint 36 gCO2 / hr
* (data source in IEA report[15])

Bidirectional Stream + media server



Carbon footprint >72 gCO2/ hr
(Encoding is more expensive than decoding)



Carbon footprint ~117.04 gCO2 / hr
(self calculated)

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Areas of energy consumption in a WebRTC Call

Client power utilization

- Apple[22]

CPU , GPU, Networking (Wi-Fi and cellular radio chips), Screen

Feedback : WebRTC uses the Extended Profile with Real-time Transport Control Protocol (RTCP)-Based Feedback (RTP/AVPF). RTCP, used for adaptive encodings, inter-stream synchronization , synchronous playback, is data-heavy processing.

ICE resolution : STUN works for a majority of WebRTC traffic, approximately 30% of connections require a TURN server []

Carbon footprint (2 participants)

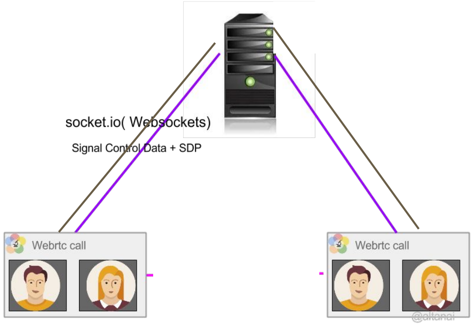
Transmission	:	t_energy (kWh) * 4
Device	:	d_energy (kWh) * 4
Server	:	s_energy (kWh) * 2

Total energy used = 0.28 kWh
Carbon Emission = 117.04 gCO2 / hr

Video Encoding : utilize CPU in construction of RTP payload

End to End encryption via SRTP

Interoperability with SIP and PSTN networks takes on added CPU consumption to provide transcoding for both signalling and media as well as additional handshakes .



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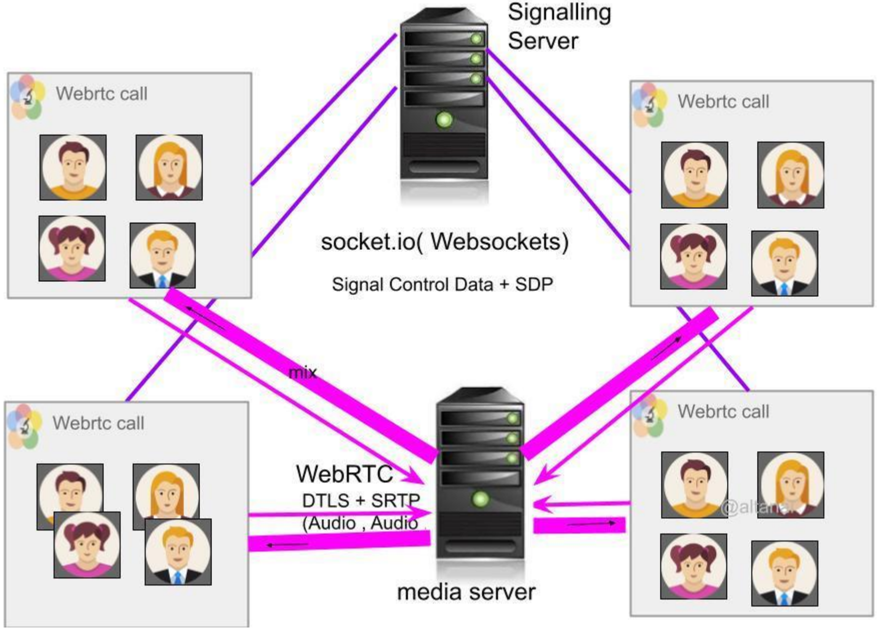
MCU based Centralized bridge/ star topology media server conference

- CPU consumption is high at the media server due to decoding , mixing and re encoding but low at receivers who only need to decode one single stream (one each for audio and video)
- CPU consumption is higher where centralised server does extensive transcoding between peers
- Extra latency caused by media server decoding necessitates the use of a jitter buffer

Carbon footprint (4 participants)

Transmission	:	t_energy (kWh) * 8
Device	:	d_energy (kWh) * 8
Server	:	s_energy (kWh) * 4

Total energy used = 0.56 kWh
Carbon Emission = 234 gCO_2 / hr



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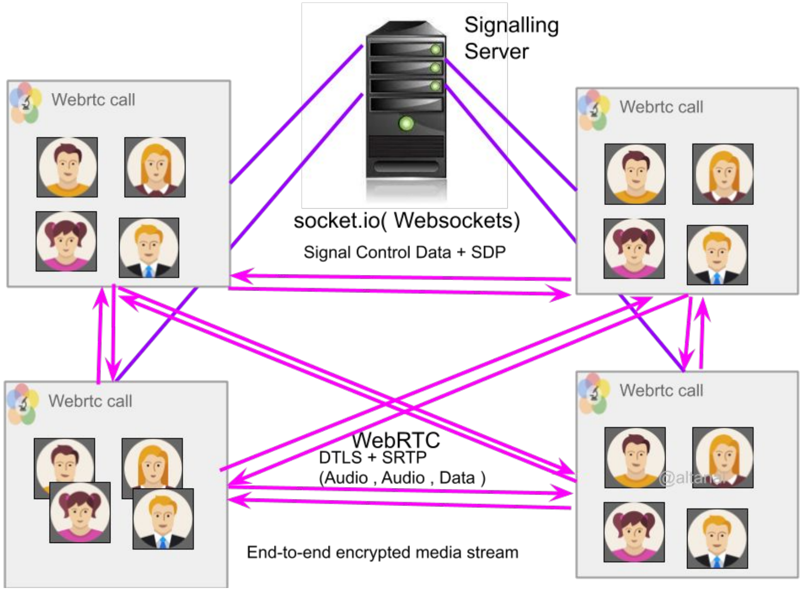
Energy consumption in Mesh WebRTC conference (Mesh)

~70% from device + ~29% transmission + 1% data centres

- Low latency due to no middle relay point for media
- Faster end to end encryption
- Multiple encoding for various resolution of stream
- Individual peer connection with each of the participants

CPU consumption is high on endpoints to avoid congestion, check quality via receivers feedbacks, render and manage streams individually for all peers.



Carbon footprint (6 peerconnection)

72(gCO2) * 6 = 432 gCO2 per hour

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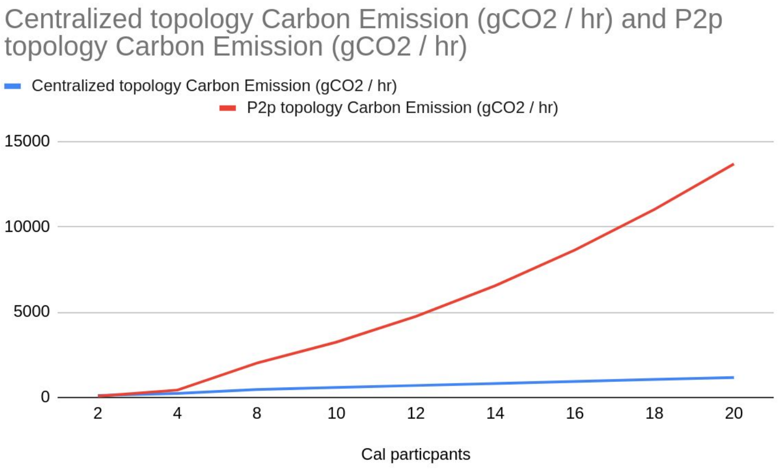
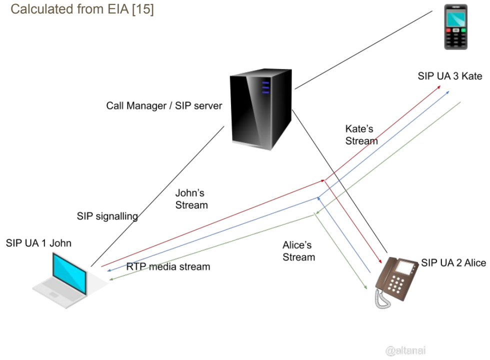
CPU utilization and Carbon Emission



Decentralized Peer-to-peer video multicast streaming (mesh)

60% from device + ~39% transmission + 1% data centres

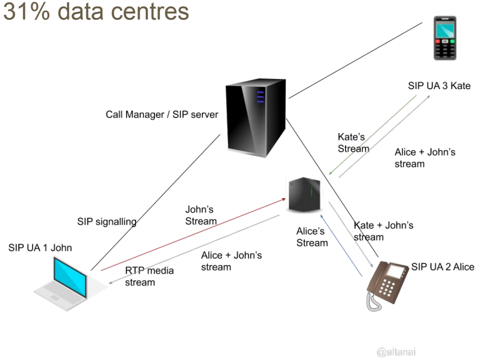
Calculated from EIA [15]



P2p streaming leads to high CPU consumption on endpoints and overall higher carbon emission

Centralized Multipoint control unit (MCU) in bridging video conferencing

~40% from device + ~29% transmission + 31% data centres



Central multicast server configuring bitrate and control encoder per endpoint leads to lower energy consumption and 40-60% lower carbon emission

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To reduce carbon emissions :

1. Reducing the energy consumption in client-side operations
2. Enable server in datacenter to do heavy media manipulation

But, how can be make energy efficient VoIP systems with a Centralized Media Server ?

Ans:

- Optimize energy efficiency in cloud- telefony
- Reduce peaks

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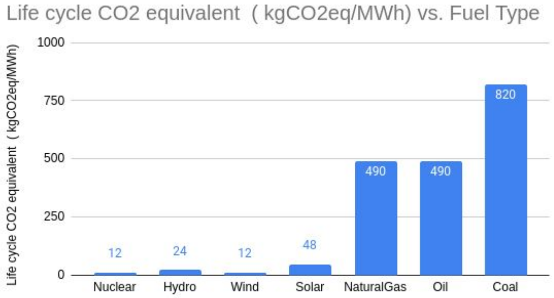
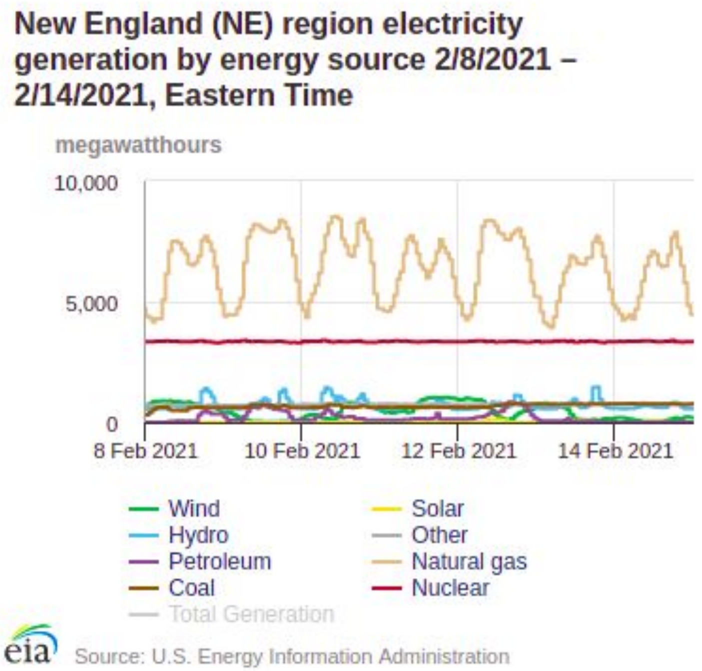
Peaking power and Carbon emission

In order to meet the peaks in electricity demand, the electricity utility providers supply the surge in power using carbon rich fuels (Natural gas, Petroleum or coal based fuels) which cause a corresponding spike in carbon emissions.





Following slides we can see a single day snapshot of electricity demand and carbon emission per minute in various utility regions of the world

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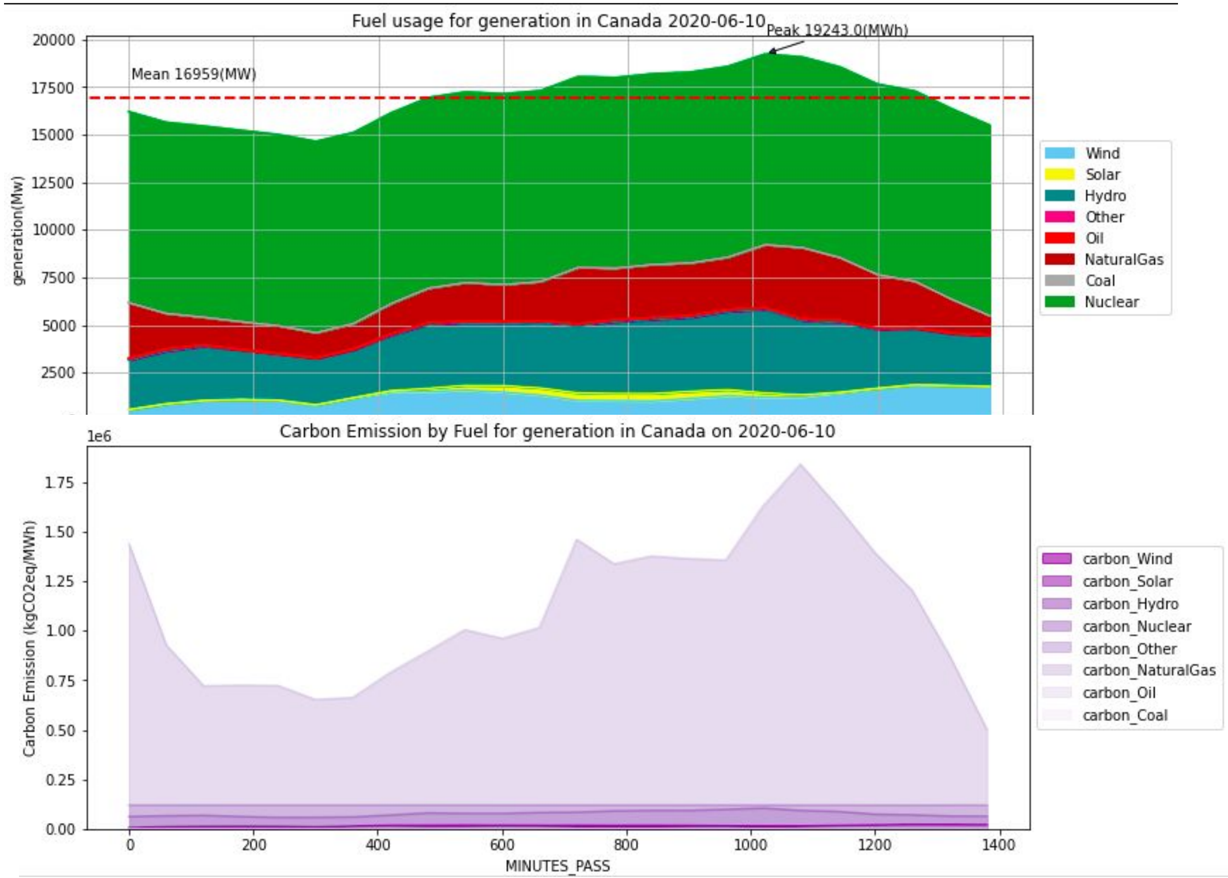
Canada



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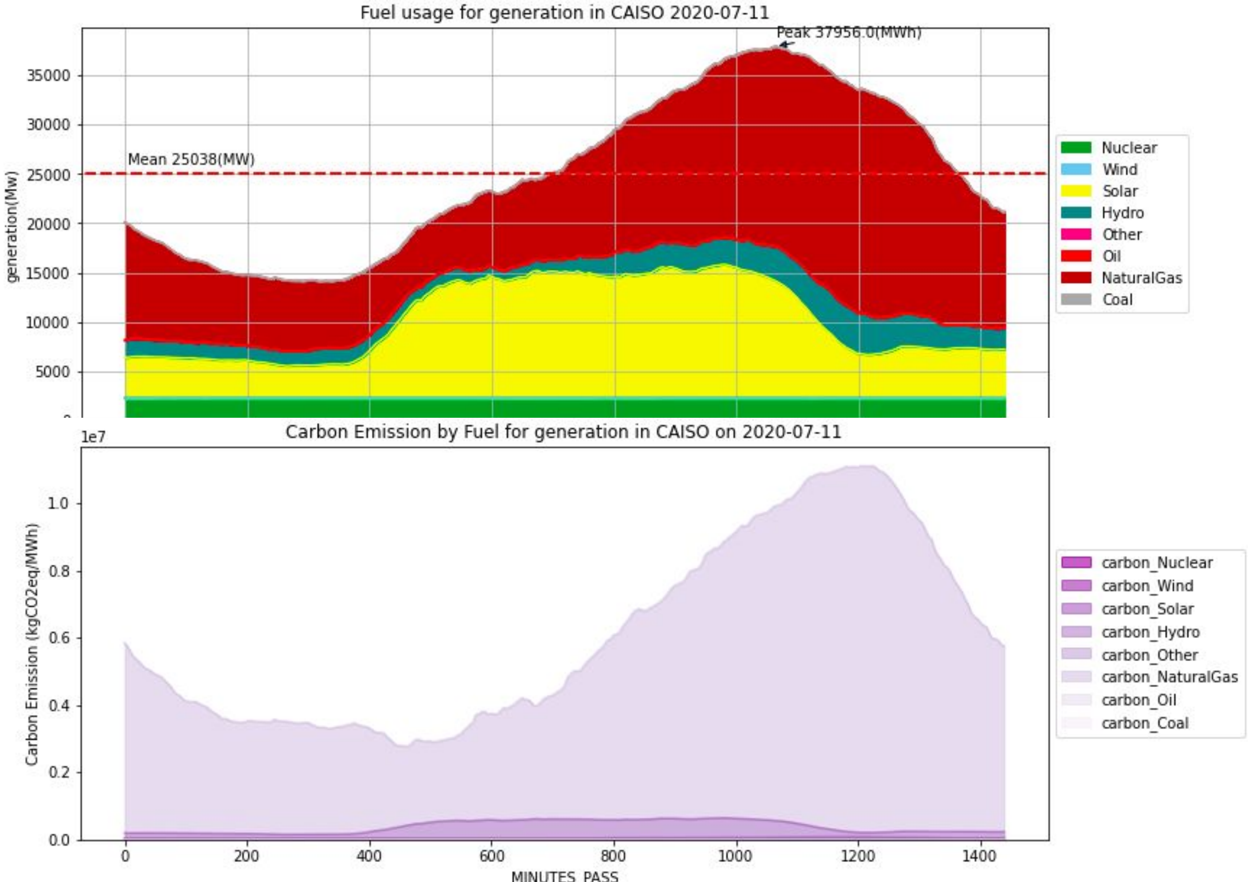
California ISO



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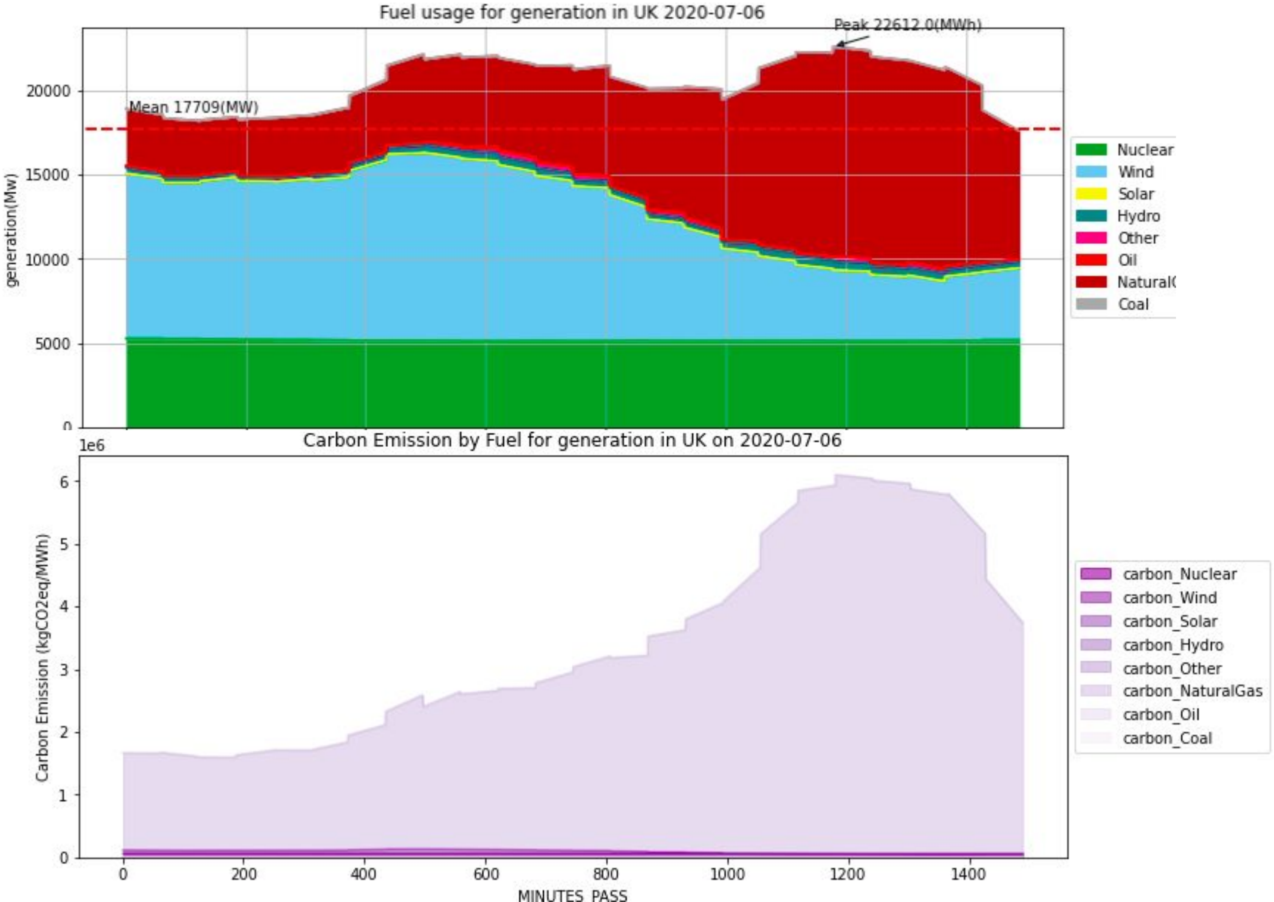
UK



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1.Electricity Storage for peak shaving

Charge batteries from off peak hours to be used in peak hours can shift peaks to night and impact carbon emission negatively

My study estimates a significant rise of upto in overall industrial carbon footprint using battery storage solutions .

Types of Battery Energy Storage

In front of the meter

- Wholesale
- Transmission and Distribution

Behind the Meter (BTM)

- Commercial
- Industrial

Energy Arbitrage saves electricity bills but is harmful in long run !

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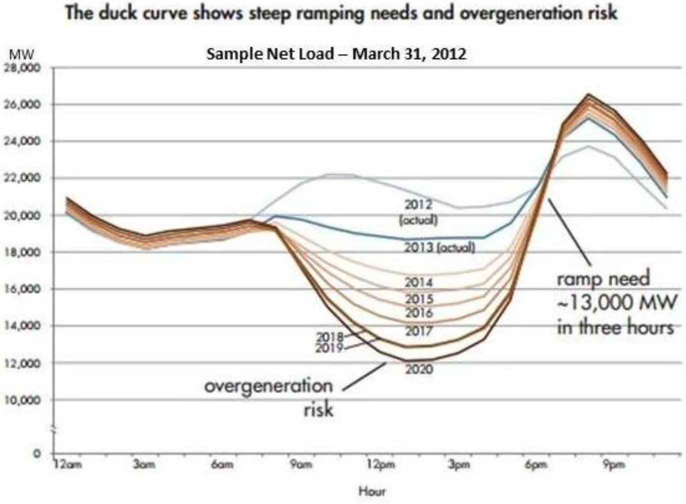
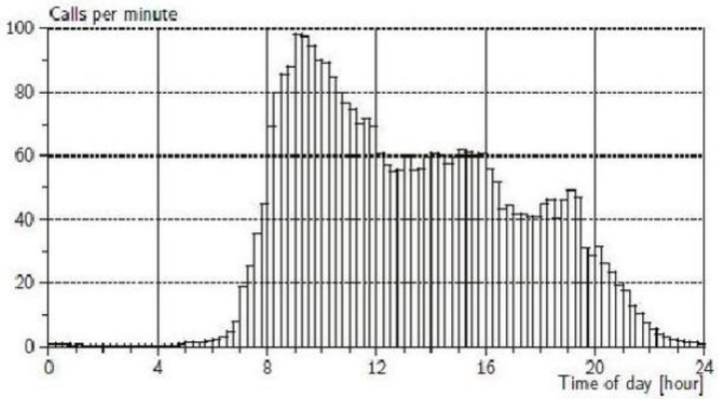
2. Battery Storage + Renewable on site integration

Aligning power consumption with onsite/ remote Solar generation peaks



(from the California Independent System Operator)



- Battery storage shaves peaks
- Avoid curtailment
- Aligned with solar generation in workdays as most local VoIP activity happens during daytime .

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3. Carbon Aware algorithms

Carbon aware CPS budget control to match allowed load for peak shaving algorithms to curb emission.
Models for
- Call density and patterns analysis
- Video conferences classifier for each location with utility provider's fuel mix

Analysing Carbon-footprint of RTC sessions on Media Server

Carbon footprint from Media Conferencing Server for a Session (Extended from Benjamin DAVY's formula [26]) :

CPU utilization in Media conference * Duration of conference
* Instance Ratio * Physical Energy Consumption(kWh) of Server
* PUE * Region Emission Factors (CO2kg/kWh)

$$\text{Instance Ratio} = \frac{\text{Instance type vCPU number}}{\text{max instance family vCPU number}}$$

$$\text{PUE} = \frac{\text{Total Facility power}}{\text{IT equipment power}}$$

Standard 2.0, Good 1.4 , Better 1.1
AWS - PUE 1.2
Google - 1.11

Region Emission Factors depends on fuel mix of the ISO supplying the power and peak discharge

CAISO - 278 gCO_2eq/kWh
Ontario - 104 gCO_2eq/kWh
New South Wales - 744 gCO_2eq/kWh
values from electrictymap.org [27]

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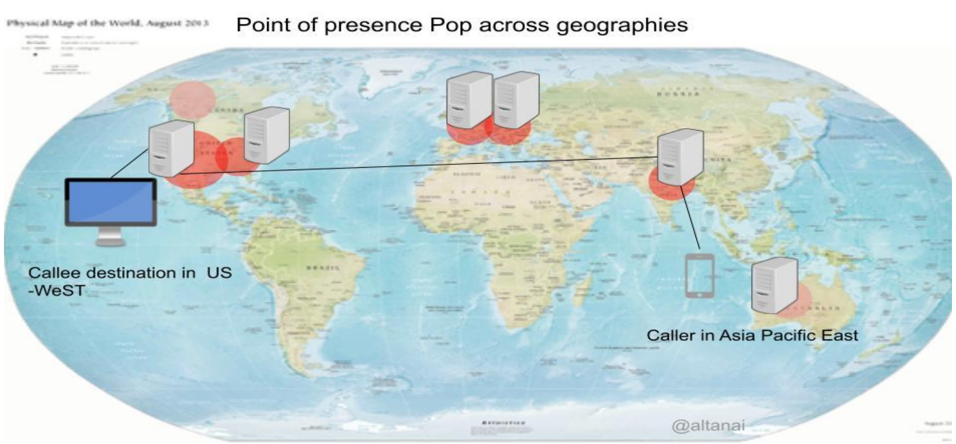
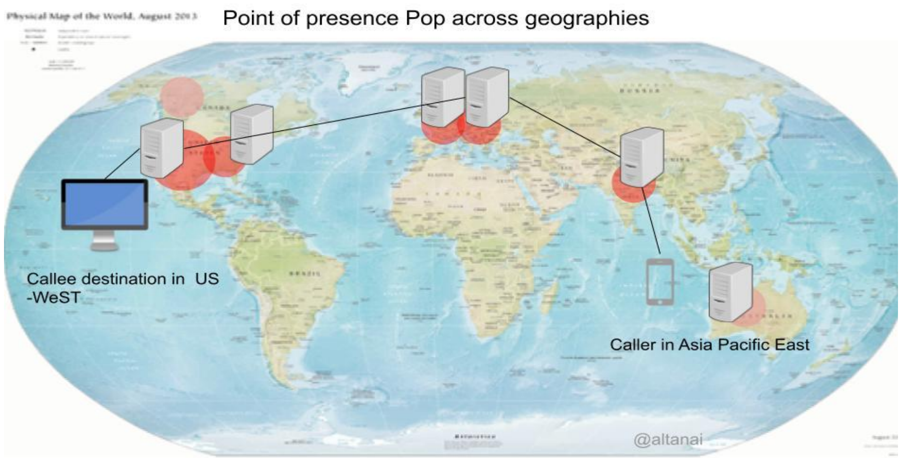
4. Media Handover
Leveraging PoP (point of presence)

A large voice communication infrastructure typically has multiple point of presence across geographies. An energy aware approach would see the RTCP feedback and dynamically compare the distance between geolocate IP and available server to route to nearest server and save on carbon cost.



Long distance calls high network usage



Lower network usage after employing Media PoP

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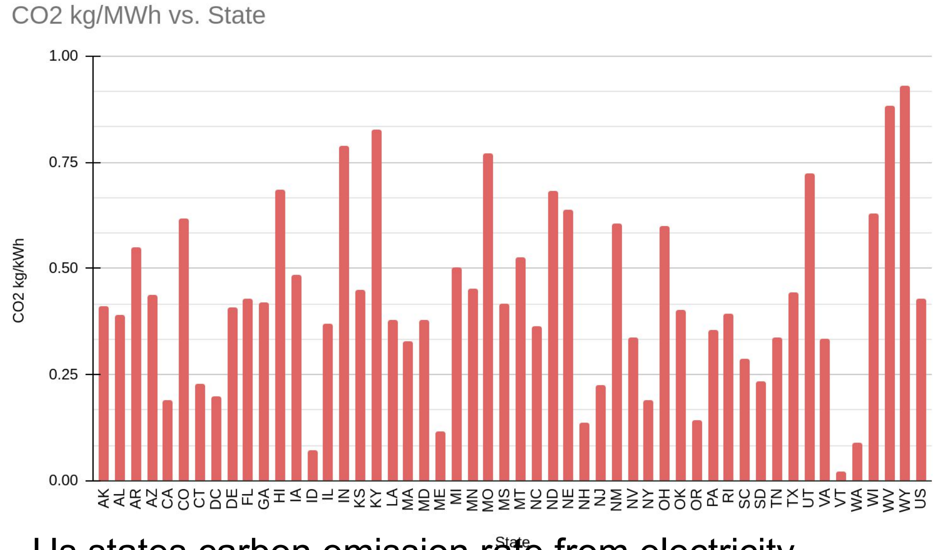
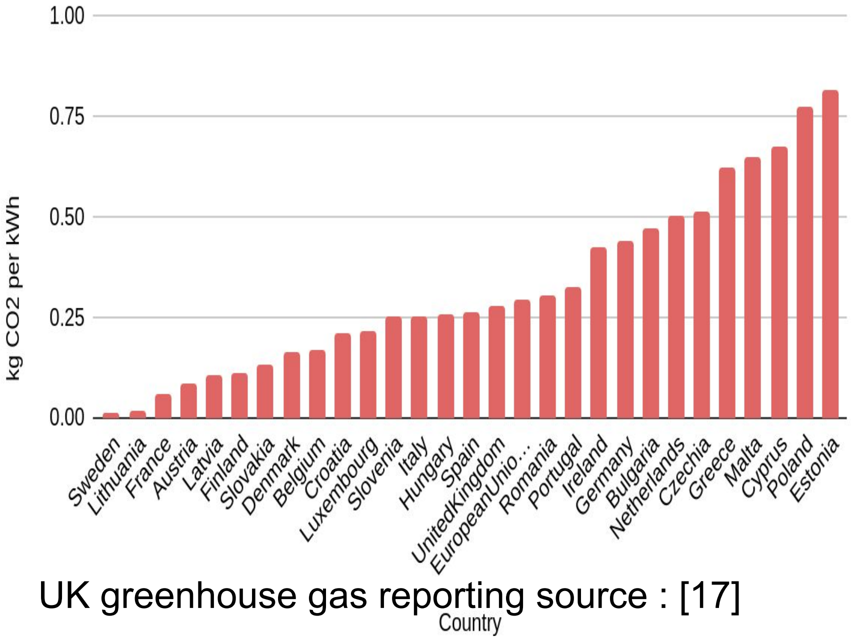
4. Handover calls to server according to their carbon emission factor in the demography

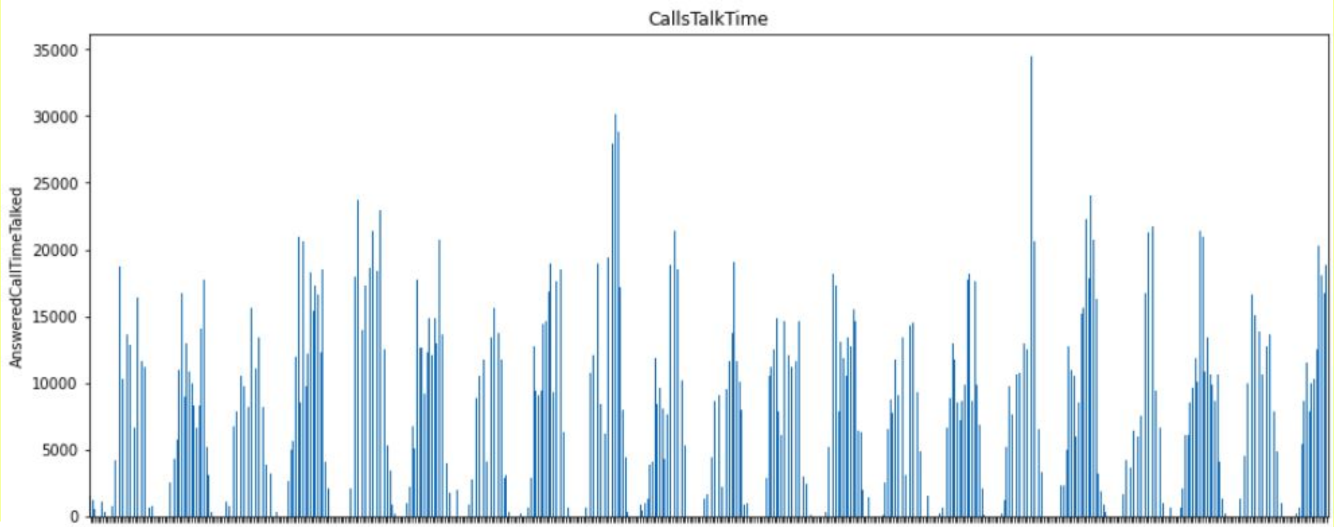


Us states carbon emission rate from electricity generation (2018 report) [16]



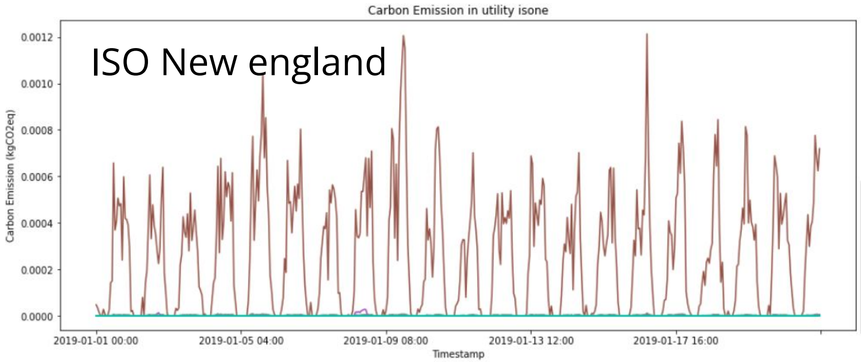
UK greenhouse gas reporting source : [17]

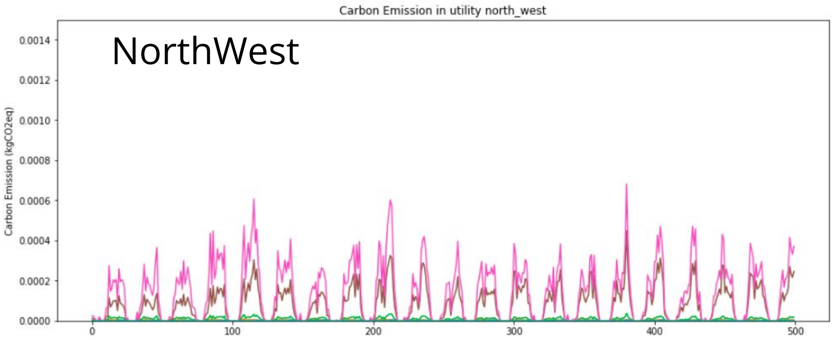
Experimental findings 1

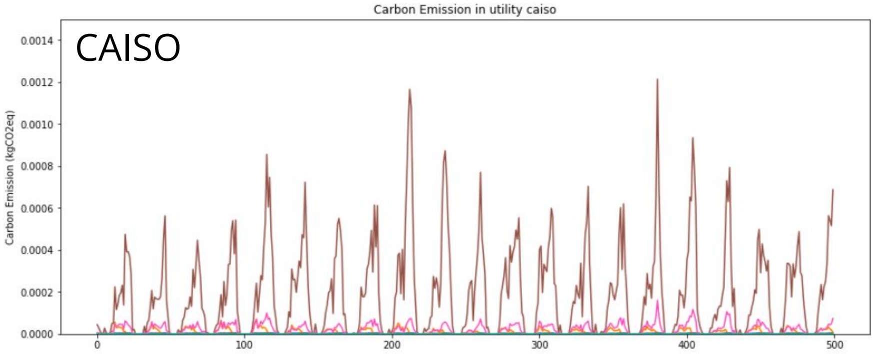


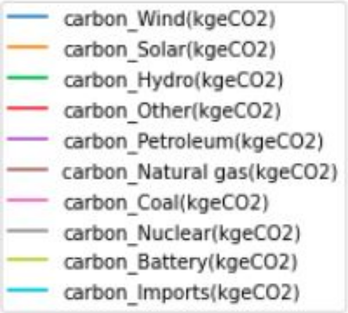
Incoming calls on tech support *dataset [27]

Carbon Emission for a call traffic in utility (~20 days) regions dataset 1

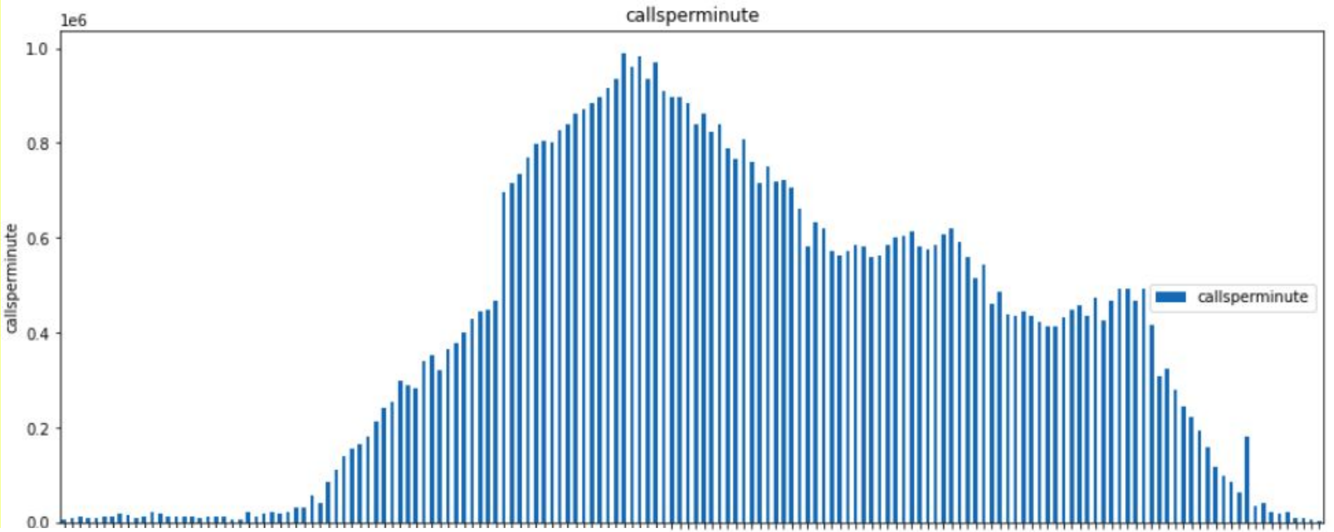






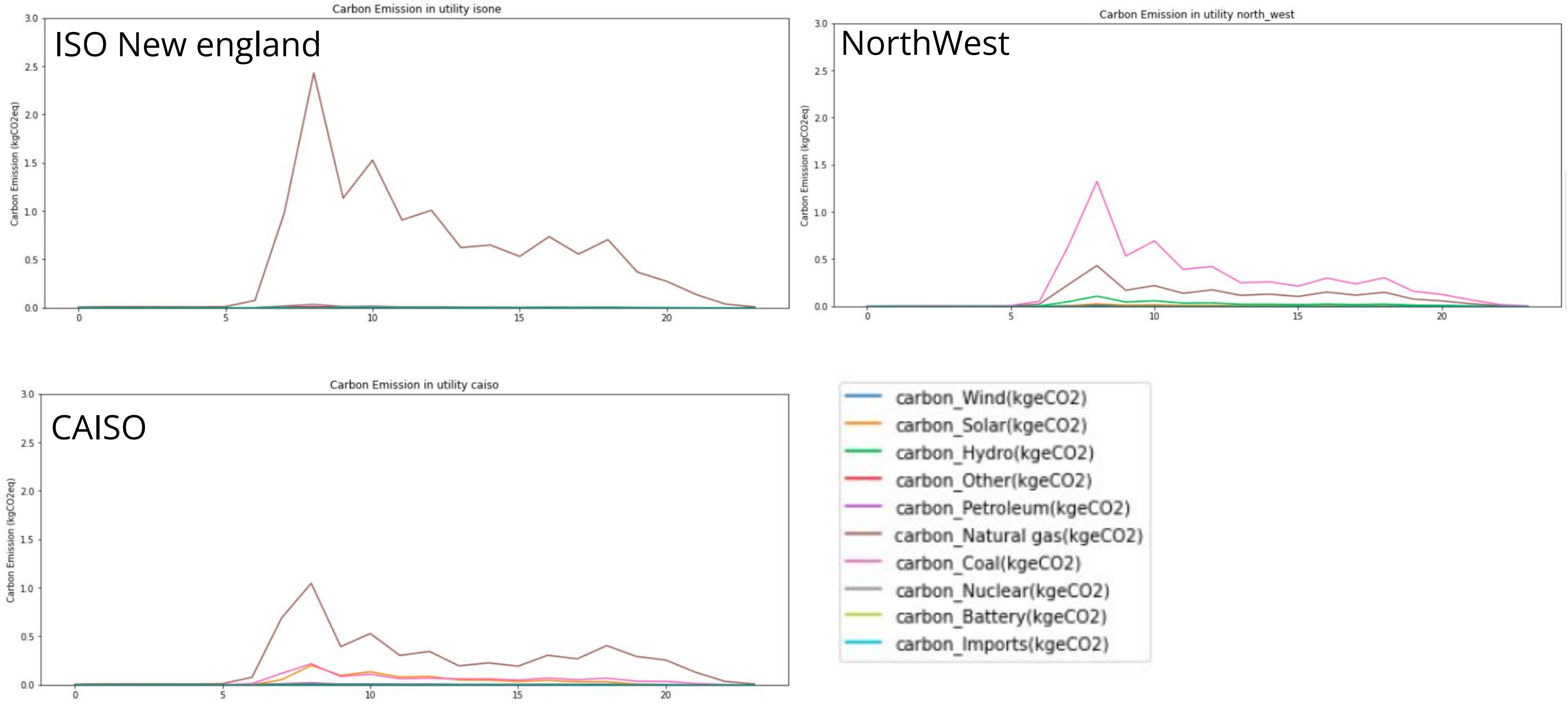


Experimental findings 2

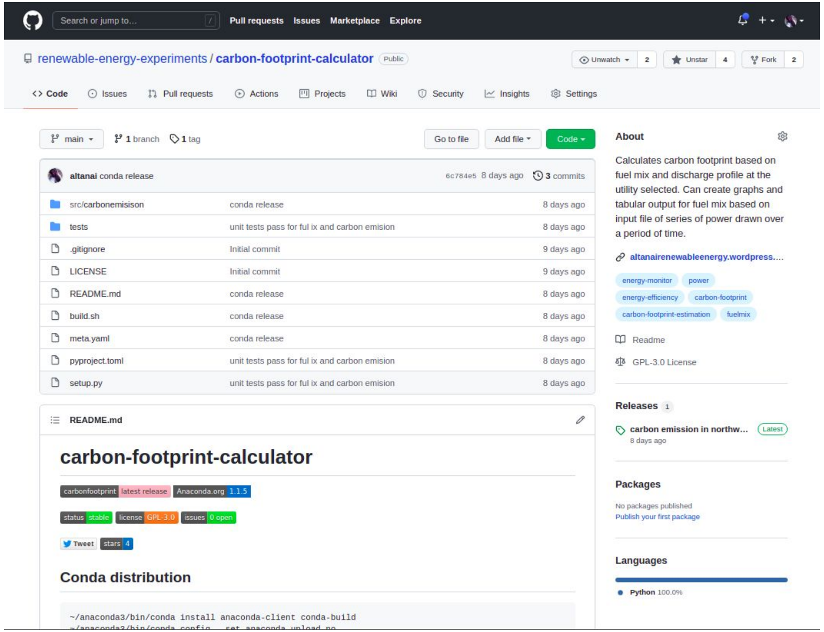


Simulated Dataset on Video Calls in a CPaaS platform

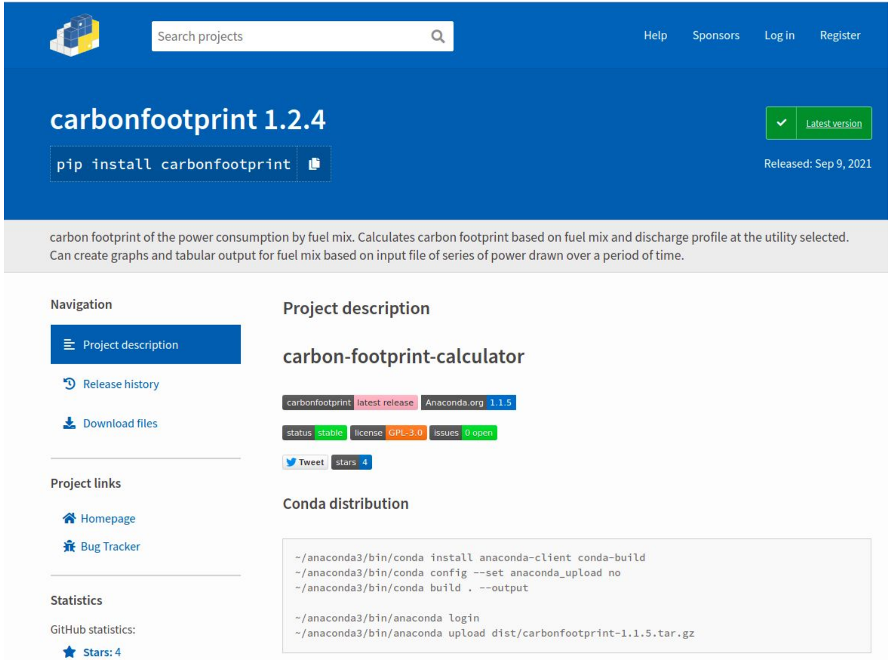
Carbon Emission for a call traffic in utility regions dataset 2



Open source Carbon Footprint Tracker for Regions



https://github.com/renewable-energy-experiments/carbon-footprint-calculator



https://pypi.org/project/carbonfootprint/

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Thank you for attending. Questions ?

@altanai

Additional reading material

Optimize energy efficiency in cloud- telefony

Energy Efficiency in

- VoIP Architecture and design
  - Plan HA (high availability) efficiently
  - Server Virtualization
  - Optimize memory access algorithms
  - Reduce Redundancy
  - Decommissioning old / outdated servers
  - Power management
  - Common Storage as Network Attached Storage
  - Sharing other IT resources
  - Consolidate individual applications on a Server
- VoIP Applications and algorithms
  - Reduce Buffering
  - Multi Core applications
  - Optimize memory access algorithms
  - Network energy Management to vary as per demand
  - Task Scheduling algorithms
  - Distributing workload based on server performance
  - Reduce challenge response mechanism when it can be avoided.
- WebRTC browser applications and native application
  - RTP topology (Mesh , MCU and SFU)
  - Call flow control
  - Transcoding and stream manipulation
  - Leverage PoP(point of presence) to optimize energy savings
  - Voice Activity detection (Mute the spectators)

Energy Efficiency in VoIP Architecture and design

Virtualize the servers

By consolidating multiple independent servers to a single underlying physical server helps retain the logical separation while also maintaining the energy costs. VM's(Virtual machines) are instances of virtualized portions on the same server and can be independently assessed using its own IP and network settings.

Reduce idle server time in HA (high availability) plan

With quick load up times and forward looking monitoring , the analyzers can monitor logs for upcoming failure or predictable downtime and infra script can bring up pre designed containers in seconds if not minutes. It isn't wise to create more than 1 standby server which does no essential work but consumes as much power.

Consolidate individual applications on a Server

Map the maximum precitable load and deduce the percentage consumption with the same . In view of these figures consolidate applications servers to be run on a single server. It ensures that while a server is drawing full power, it is also showing relatable utilization.

Reduce redundancy

While it is a common practise to store multiple copies of data such as CDR (call detail records) and archive historical logs for later auditing, it is not the most energy efficient way since it ends up wasting storage space. Skim only the critical parts and discard the rest. Compress the less referenced logs and shift to Network storage.

Hardware based approaches such as energy star rating, air conditioning , placement of server racks , air flow etc have not been touched upon in this article they can be read from energy star report here [5]

Energy Efficiency in VoIP Applications and algorithms

In theory, energy efficient algorithms would take less processing power, run fewer CPU cycles and consume less memory.

Reduced Buffering and Optimize memory access

Change to better compression formats to save transmission cost (bitrate downsizing)
HEVC and AV1 are more efficient than older codecs

Network energy Management to vary as per demand
Calculated tradeoff between power consumption and network performance on various RTP topologies

Task Scheduling algorithms
Some recent researched frameworks and models take Co2 emission into perspective while allocating resources according to queuing model. The most efficient ones not only bring down the carbon footprint but also the high operating cost [11].

Centralised operation
Instead of operating many servers at low CPU utilization at end or small tier servers, combine the processing onto larger server that operate at higher utilization.Modern machine learning programs are computationally intensive, and their integration in VoIP systems for tagging , sentiment analysis , voice quality analysis is increasingly adding additional more strain on already heavy processing of media server with activities such as transcoding, recording, playback and multiplexing .

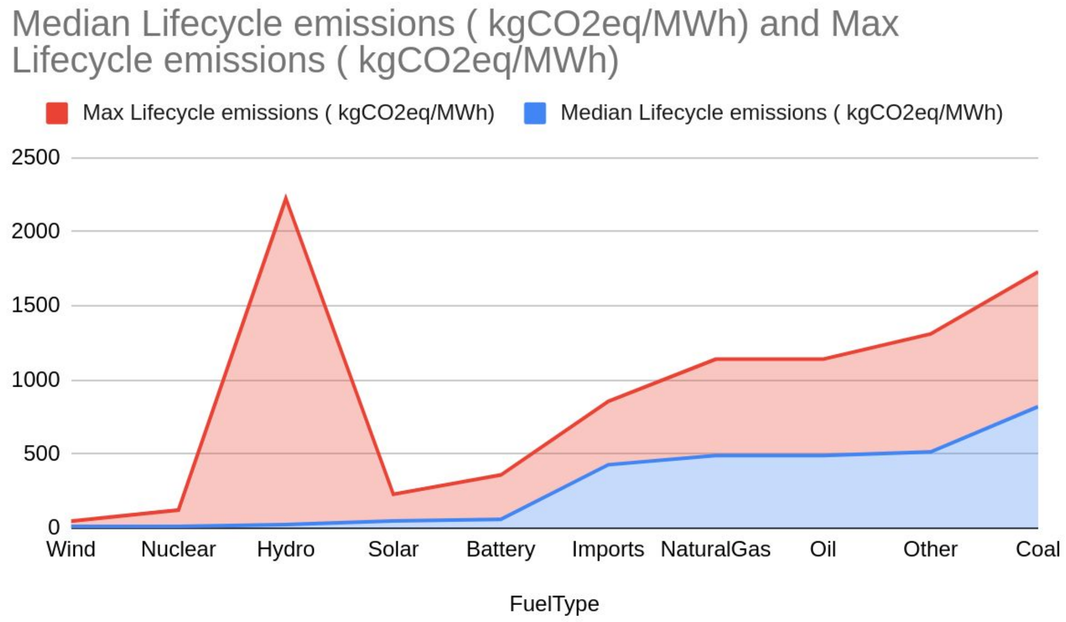
Distributing workload based on server performance

Aggregate tasks and run as serverless, asynchronous jobs instead of standalone processes . Categorize server workloads based on server performance .Thermal aware workload distribution also helps reducing power consumption and consequently electricity consumption in cooling .

Carbon Debt

While the fossil fuels as carbon rich sources have an obvious large share in Carbon emission during power, the hidden “carbon debt” is LCA of Caron eq emission from the manufacturing, production and operation of renewable energy systems.

- Hidden Cost in Solar – Manufacturing process of PV cells
- Hidden cost in Wind – Wind turbines and nuclear plants need a lot of steel and concrete.
- Hidden cost in nuclear plants – centrifuges that separate nuclear fuel also rack up a big electricity bill.

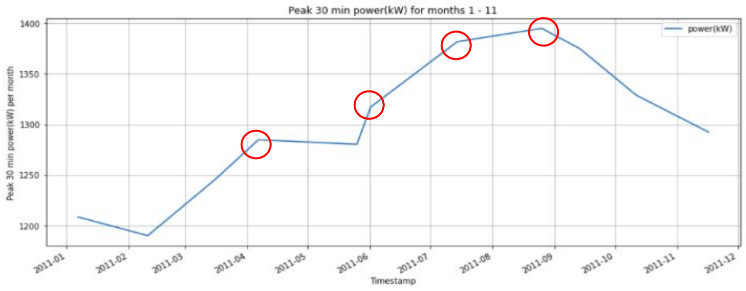


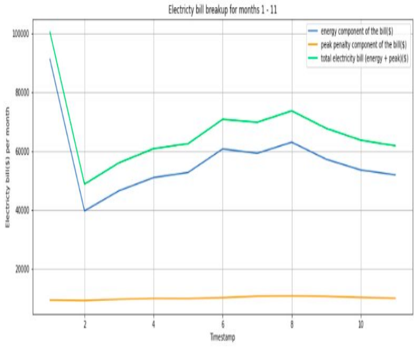
solar PV works out to about 50g of CO_2 per kWh compared to coal’s 975g of CO_2 per kWh, or about 20x “cleaner.”

– TREEHUGGER HTTPS://WWW.TREEHUGGER.COM/HOW-MUCH-CO-DOES-ONE-SOLAR-PANEL-CREATE-4868753)

Demand (kW) Charges for Commercial and Industrial bill

peak power makes between 9.202% to 18.689% of the total monthly bill





2013 Large General Service - City Rates

Peak energy charge/kWh	$0.0657
Off-peak energy charge/kWh	$0.0438
Peak demand charge/kW	$1.52
Off-peak demand charge/kW	$0.23
Minimum charge/day	$16.39
Transformer Investment/kW	$0.23

Utilities apply demand charges (usually to industries and commercial customers) in addition to base and energy charges with other taxes or benefits. They can very quickly pile up to become a significant portion of electricity bill based on peaks in consumption

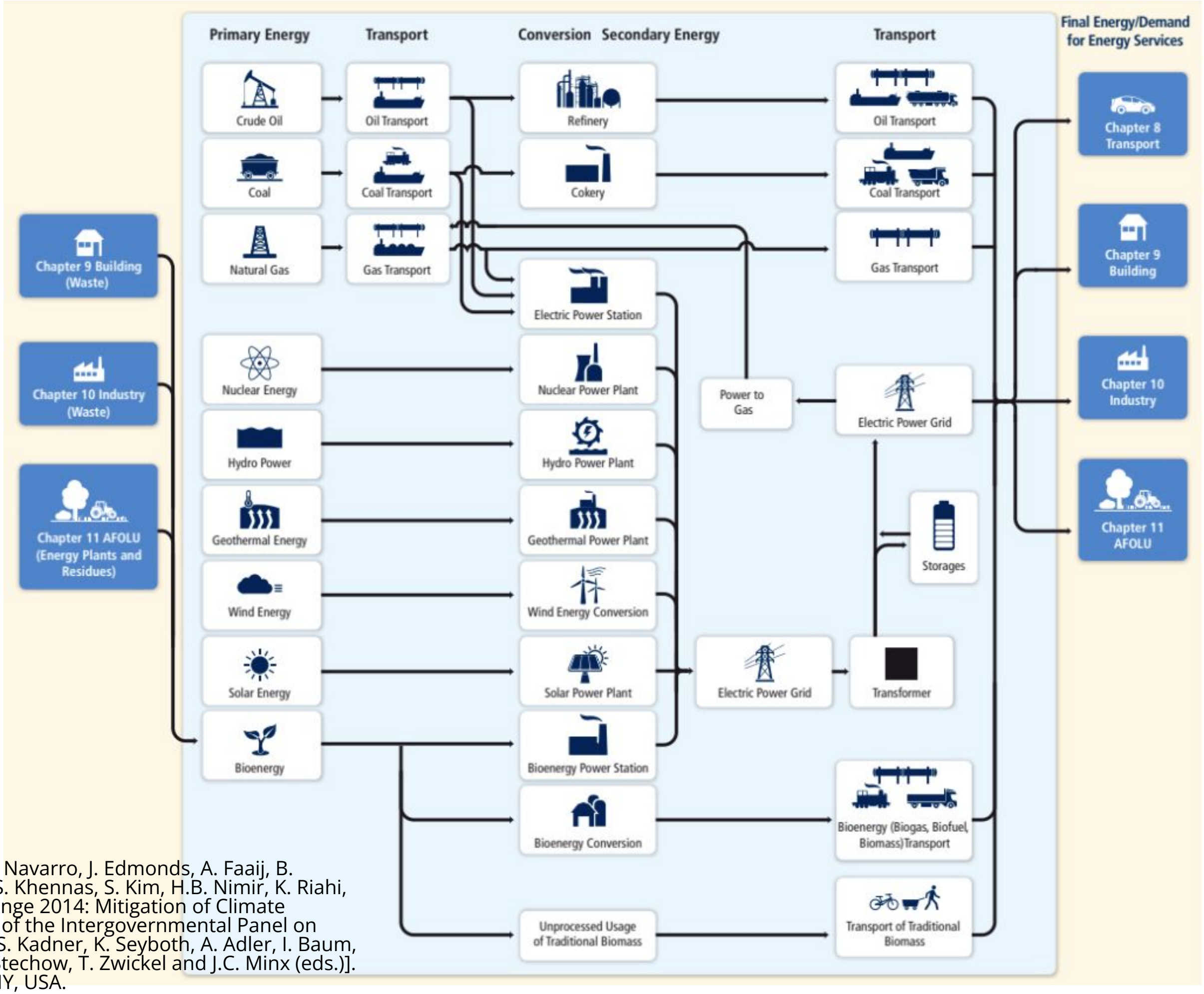
Maximum Consumption : Based on the maximum amount of power that a customer used in any interval (typically 15 minutes) during the billing cycle., some rate structures include multiple types of demand charges, with

Peak and off Peak hour consumption : different demand rates during different times such higher charges during hours of peak demand, and lower charges during “partial-peak” or “off-peak” hours (time of use rates, Sunday , night hours and public holidays)

Seasonal : Some utilities have demand charge separated based on summer and winter months

Why Do Utilities Apply Demand Charges? Demand charges try to discourage sudden peaks and incentivize customers to spread their energy usage over time. In peak hours when most energy is drawn from the grid , utilities have to keep expensive carbon rich power sources on standby to supply the immediate burst in requirement on a short basis. This is carbon rich fuel and significantly adds up one emission. To prevent low usage customers from having to cover this unequal demands from high consumption industries , utility providers include a demand charge for non-residential customers .

Illustrative supply Paths for electricity

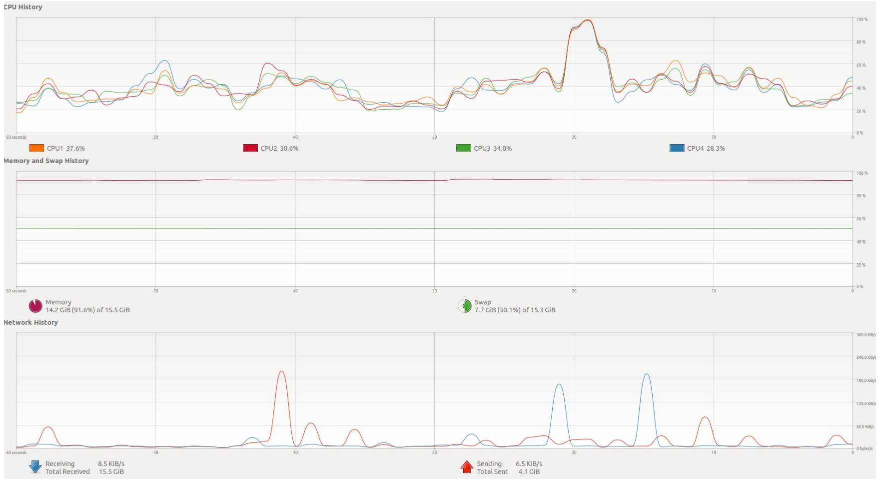


Source : Bruckner T., I.A. Bashmakov, Y. Mulugetta, H. Chum, A. de la Vega Navarro, J. Edmonds, A. Faaij, B. Fungtammasan, A. Garg, E. Hertwich, D. Honnery, D. Infield, M. Kainuma, S. Khennas, S. Kim, H.B. Nimir, K. Riahi, N. Strachan, R. Wiser, and X. Zhang, 2014: Energy Systems. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Memory	15.5 GiB
Processor	Intel® Core™ i7-7500U CPU @ 2.70GHz × 4
Graphics	Intel® HD Graphics 620 (KBL GT2)
GNOME	3.28.2
OS type	64-bit

Client Load

Browser based Webrtc session



Signaller on MCU media Server on Ubuntu AWS EC2 C5 large (compute-intensive workloads)

Ubuntu Server 20.04 LTS (HVM),EBS General Purpose (SSD)
vCPU 2 - Turbo CPU clock speed of up to 3.6 GHz.
Intel Xeon Platinum 8000 series processor