# Life Cycle Assessment for Stanford Information Technology

## Introduction and Background

### Servers

- A server is a piece of computer hardware or software that provides various services, such as storing and managing network data

### On-Premise Server vs. Cloud Computing

- On-premises systems use self-own servers installed and maintained by in-house IT departments
- Cloud systems use remote servers via the internet offered by cloud service providers

### On-Premises Options

- On-premise servers at Stanford's Forsythe data center (on-campus)
- On-premise servers at Stanford Research Computing Facility (SRCF)

### Cloud Environment

- Single cloud environment, Amazon Web Services (AWS)

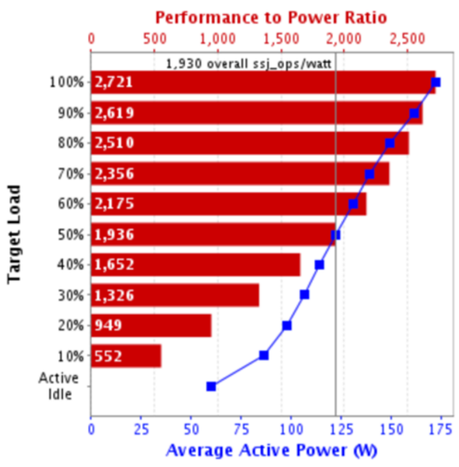
### Significance

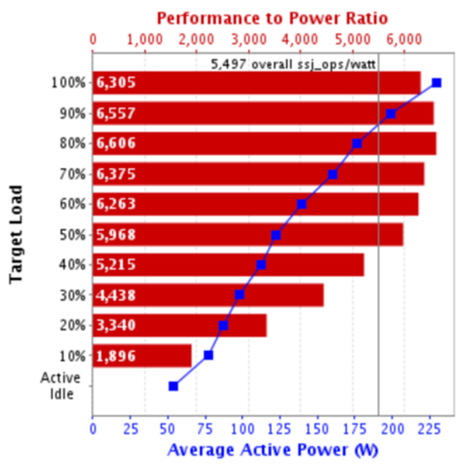
- U.S. data centers consumed more than 2% of all U.S. electricity use in 2013
- Address emissions from the IT & Telecommunications category in Stanford for a Scope 3 Emissions Program launched by Stanford University
- Compare the currently purchased product and seek a more sustainable alternative

## Analysis Methods and Process Flows

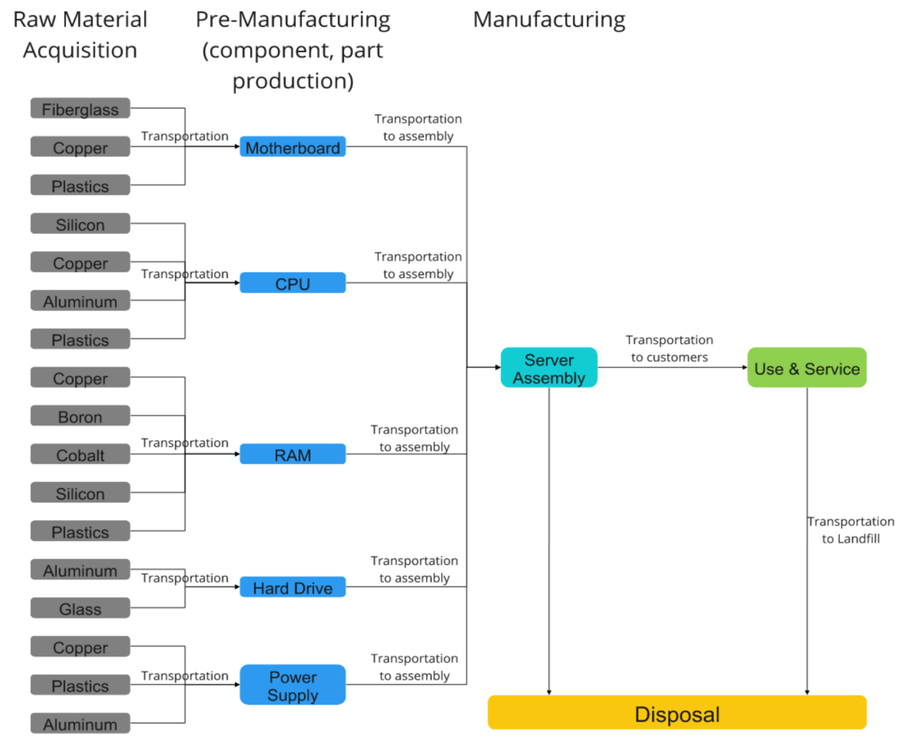
### Functional Unit

- The functional unit for the study is a Stanford server (PowerEdge R610) operating at 30% of the full performance for 4 years ( 1.78x1013 ssj_ops)




### Process Flow Diagram




### System Boundary

- The boundary of our life cycle analysis include the environmental impacts of the Dell R610 and R720 server across component manufacturing, assembly, distribution, and use phase (End-of-life phase is excluded)

### Comparative Methodology

- Two types of servers are assumed for on-premise (Dell R610) and Cloud computing (Dell R720)

### Production Phase

| Type | Mass (kg) | Calculation | SimaPro Equiv. Piece |
|---|---|---|---|
| **SimaPro Computer** | 11.3 | N/A | 1 |
| **Dell PowerEdge R610** | 17.69 | $\frac{17.69}{11.3} = 1.57$ | 1.57 |
| **Dell PowerEdge R720** | 28.1 | $\frac{28.1}{11.3} = 2.49$ | 2.49 |

### Transportation

- Different travel methods and point-of-use are assumed

### Use Phase

- Due to constant demand from Stanford, we only account for 10.8% emission caused by cloud computing at all phases.
- Different data center PUE and electricity grid are modified for on-premise (Forsythe/SRCF) and Cloud computing (Dell R720)

### Sensitivity Analysis Methodology

Based on the use phase of the on-premise server at Forsythe

- 20% at lowest and 50% at highest maximum workload
- 5% uncertainty for the power usage efficiency
- 0.8% uncertainty in the measurement of active idle power

**Group 9: Jianqi Xue, Minxue Gu, Lillian Hung**
**Xuhuan Zhao, Mingxi Zhang**
**Industry Sponsor: Stanford Office of Sustainability**

CEE 226 – Life Cycle Assessment for Complex Systems
Professor Michael Lepech

*Engineering towards Sustainability*
STANFORD CIVIL & ENVIRONMENTAL ENGINEERING

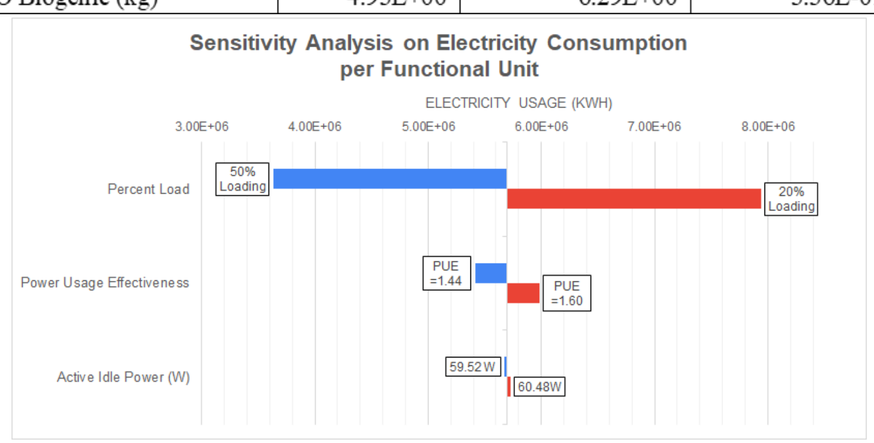
# Quantitative Results and Analysis

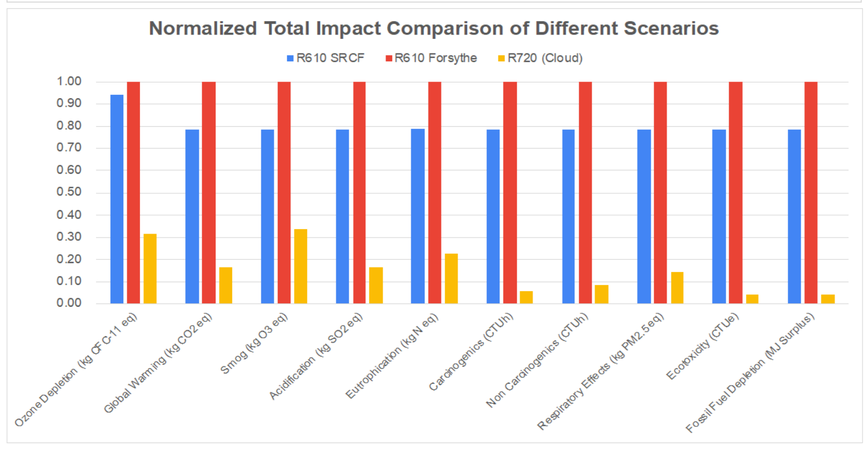
## Comparative impact assessment for three Scenarios

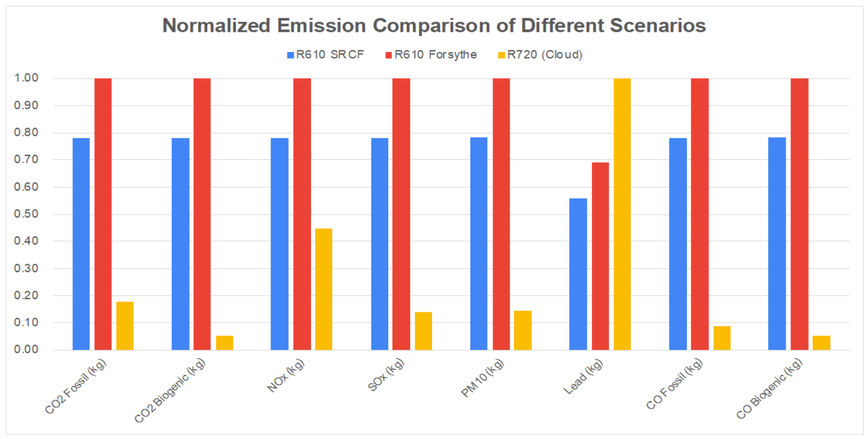
| Summary of Impact Assessment | | | |
|---|---|---|---|
| **Impact Categories** | **R610 at SRCF** | **R610 at Forsythe** | **R720 (Cloud)** |
| Ozone Depletion (kg CFC-11 eq) | 3.12E-05 | 3.32E-05 | 1.04E-05 |
| Global Warming (kg $CO_2$ eq) | 1.96E+06 | 2.51E+06 | 4.14E+05 |
| Smog (kg $O_3$ eq) | 6.16E+04 | 7.87E+04 | 2.66E+04 |
| Acidification (kg $SO_2$ eq) | 1.69E+04 | 2.15E+04 | 3.58E+03 |
| Eutrophication (kg N eq) | 1.75E+02 | 2.22E+02 | 5.03E+01 |
| Carcinogenics (CTUh) | 8.20E-03 | 1.05E-02 | 5.95E-04 |
| Non Carcinogenics (CTUh) | 1.07E-01 | 1.36E-01 | 1.16E-02 |
| Respiratory Effects (kg $PM_{2.5}$ eq) | 9.86E+02 | 1.26E+03 | 1.80E+02 |
| Ecotoxicity (CTUe) | 2.61E+06 | 3.32E+06 | 1.36E+05 |
| Fossil Fuel Depletion (MJ Surplus) | 4.46E+06 | 5.70E+06 | 2.35E+05 |

| Life Cycle Cost Analysis | | | | |
|---|---|---|---|---|
| | **On-Premise Servers** | | **Cloud Server (R720)** | **Cloud Service (R720 Equivalent)** |
| | **SRCF** | **Forsythe** | | |
| Useful Life (Years) | 4 | 4 | 4 | 4 |
| Purchase Price ($) | 15,828 | 15,828 | 17,242 | Service Price: $1,220/yr |
| Interest (%) | 4 | 4 | 4 | 4 |
| Installation Cost ($/server) | 626 | 626 | 626 | N/A |
| Replacement Cost ($/server) | N/A | N/A | N/A | N/A |
| Salvage Value ($/server) | 200 | 200 | 218 | N/A |
| Disposal Cost ($/server) | 20 | 20 | 20 | N/A |
| Energy Cost ($/yr.) | 241 | 188 | 170 | N/A |
| Maintenance Cost ($/yr.) | 900 | 900 | 325 | N/A |
| Operating Cost ($/yr.) | 115 | 115 | 115 | N/A |
| Downtime Cost ($/yr.) | 900 | 900 | 900 | N/A |
| Total Future Costs ($) | -180 | -180 | -198 | N/A |
| Present Value of Future Costs ($) | -154 | -154 | -169 | N/A |
| Total Annual Costs ($) | 2,156 | 2,103 | 1,510 | N/A |
| Present Value of Annual Costs | 7,826 | 7,634 | 5,481 | N/A |
| Total Life Cycle Cost in Present Value ($) | 24,126 | 23,934 | 23,180 | 4,428 |
| **Allocated LCC in Present Value ($)** | **24,126** | **23,934** | **2,508** | **4,428** |

| Total Emission | | | |
|---|---|---|---|
| **Airborne Emissions** | **R610 SRCF** | **R610 Forsythe** | **R720 (Cloud)** |
| CO2 Fossil (kg) | 1.74E+06 | 2.22E+06 | 3.91E+05 |
| CO2 Biogenic (kg) | 5.76E+04 | 7.35E+04 | 3.86E+03 |
| NOx (kg) | 1.79E+03 | 2.28E+03 | 1.02E+03 |
| SOx (kg) | 1.56E+04 | 1.99E+04 | 2.77E+03 |
| PM10 (kg) | 1.07E+02 | 1.37E+02 | 1.99E+01 |
| Lead (kg) | 1.70E-02 | 2.11E-02 | 3.04E-02 |
| CO Fossil (kg) | 1.32E+03 | 1.69E+03 | 1.47E+02 |
| CO Biogenic (kg) | 4.93E+00 | 6.29E+00 | 3.36E-01 |




## Main Results

- The use phase has the largest proportion of pollutants (more than 99%) and the strongest impact
- The production process has noticeable lead emissions and most ozone depletion the impact
- R720 produces more emissions than R610 at the production stage but much less after allocation
- R610 at SRCF has the greatest emission at the use stage, except lead. On-premise server (R610) at the transportation stage has a larger impact in all impact categories except for ozone depletion

## Sensitivity Analysis Based On-Premise Server at Forsythe

- The uncertainty in the load percentage of the server will have the largest influence on the electricity consumption of the server

# Conclusions and Recommendations

## Conclusions

Life cycle analysis of three data solutions for Stanford IT department

- Cloud servers have much fewer environmental impacts than on-premise servers
- The SRCF has superior environmental performance than the Forsythe data

## Recommendations

- Through quantification, we find Cloud Computing the most economical and environmentally friendly solution and recommend transferring parts of its on-premises data to the cloud
- We recommend that confidential data be stored in the SRCF.
- We recommend having servers run at a greater utilization rate to optimize the performance-to-power ratio and thereby reducing energy consumption