Energy Efficient HPC in Metropolitan Environments

supply and demand side management

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representing
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On IT and Energy

A growing appetite for Joules

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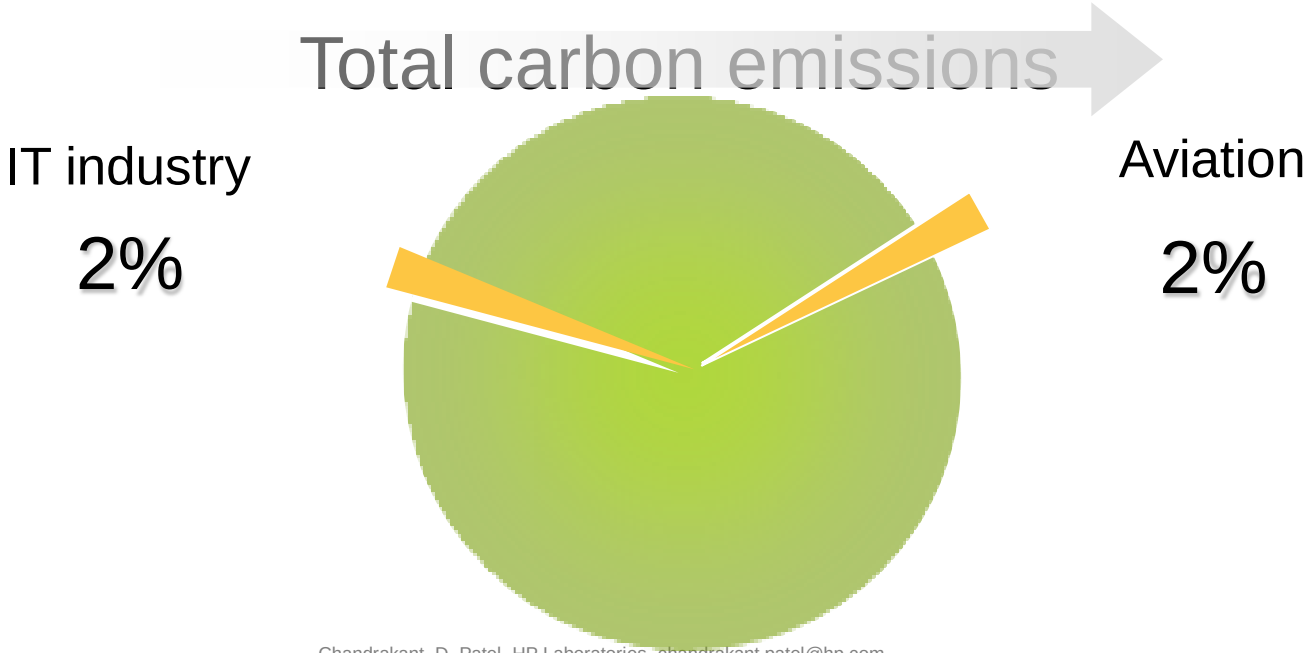
IT Energy Consumption

IT represents 2% of total energy consumption (growing double-digit per year)

But IT can also help addressing most of total energy consumption

(Industrial: 31%, Transportation: 28%, Residential: 22% and Commercial: 19%)



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IT consumption: An explosion of needs and applications

- **Consumer**
  - Access to Data (text, sound, images, video): TBs per person
  - Social interactions (voice, data, images): Mb/s of I/O per person
  - Digital TV/ Move to 3D: forget square, enjoy cubic!
- **Enterprise**
  - Acquisition, Processing and Displaying of Enterprise Data: PBs
  - Business Intelligence: Data Analysis, Simulation, Decision
  - Communication: E-mail, Virtual presence, Immersion

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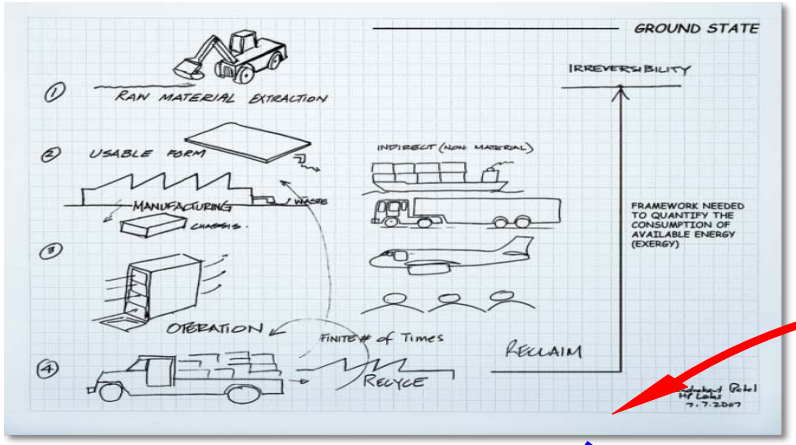
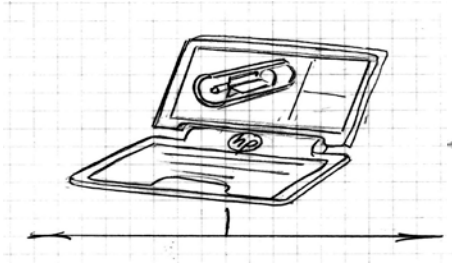
Joules: Currency of the flat world

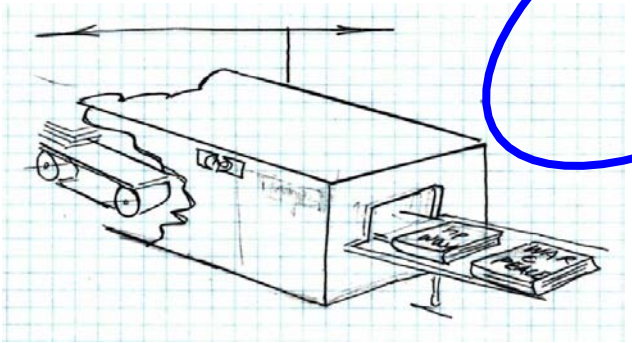
in the cloud...

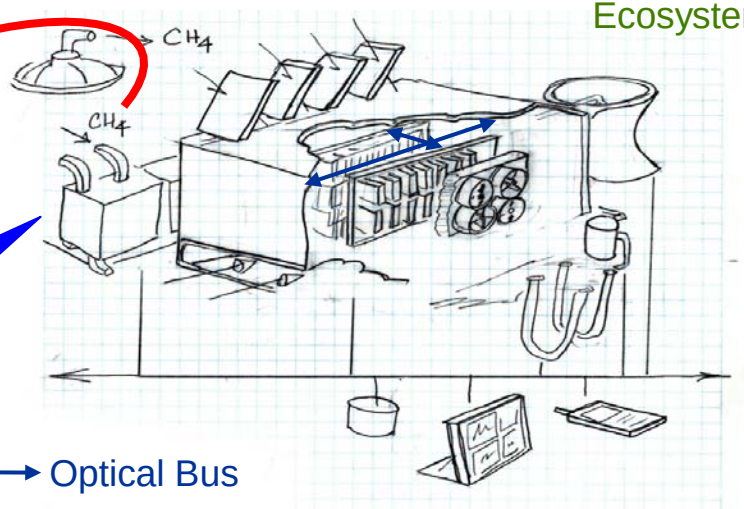
Joules of exergy destroyed per transaction?





Enabled by a Sustainable IT Ecosystem





Optical Bus

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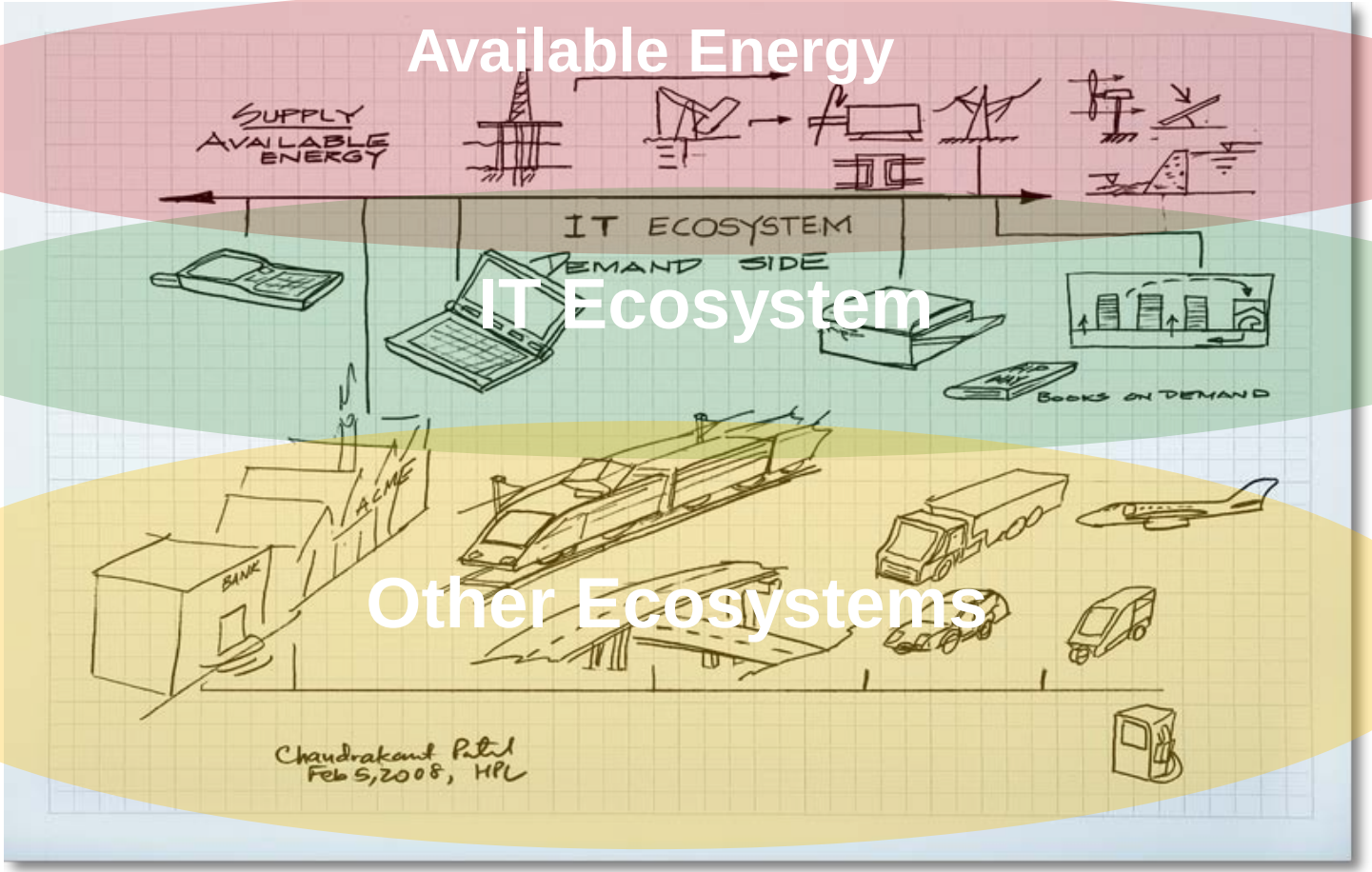
Sustainable IT Ecosystem



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On HP Labs' Research on Sustainability

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HP LABS AROUND THE WORLD

Global talent, local innovation

PALO ALTO

BRISTOL

ST. PETERSBURG

BEIJING

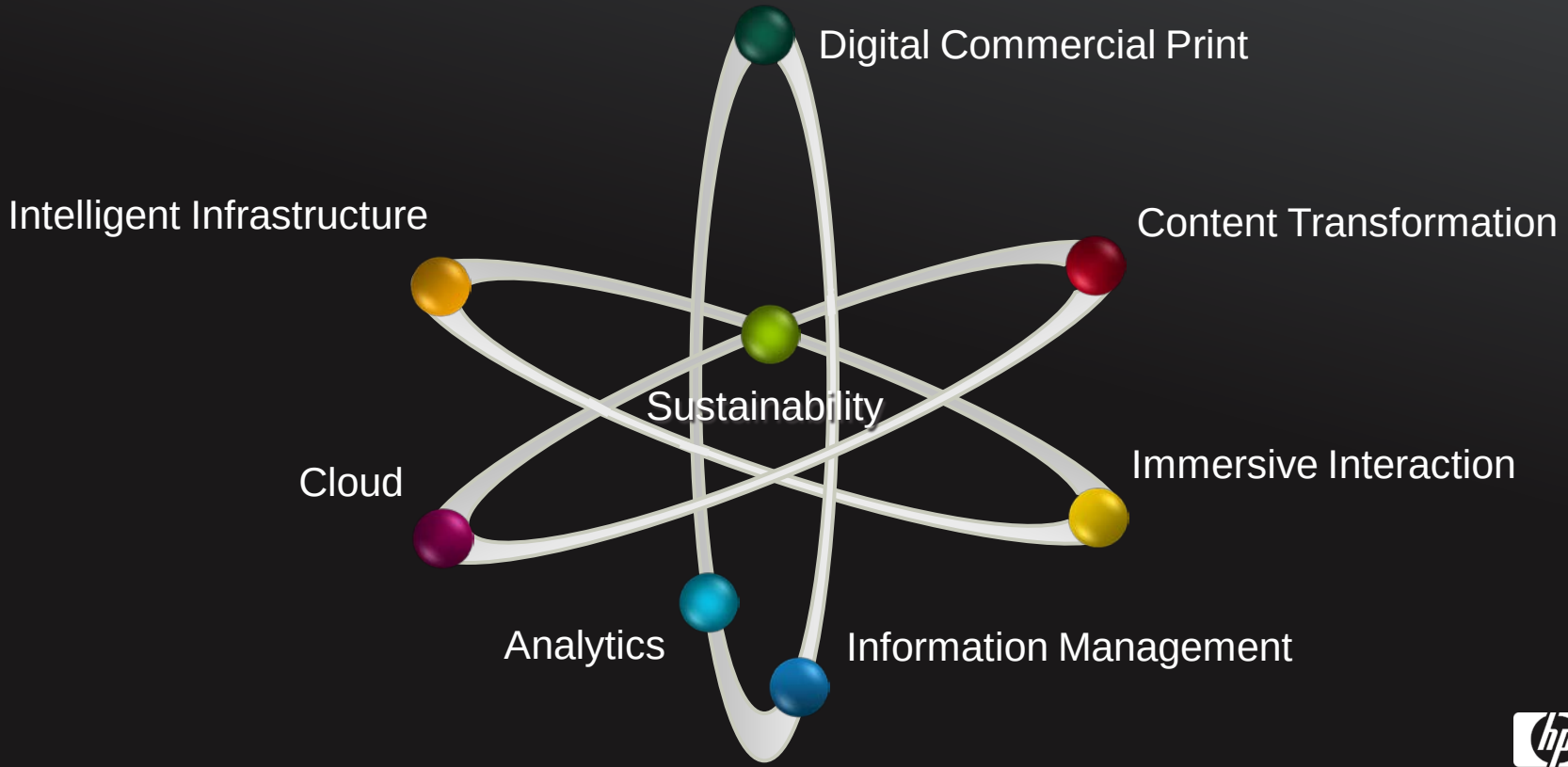
BANGALORE

SINGAPORE

HAIFA

HP LABS RESEARCH PORTFOLIO

The next technology challenges and opportunities



CeNSE

Central Nervous System for the Earth

RESEARCH CONTRIBUTION

- Networks of billions of low-cost, self-powered, nano-scale sensors
  - Acute sensitivity of minute changes
- Dynamically provision resources in real time
  - Seismic oil exploration
  - Structural integrity
  - Merchandise tracking
  - Energy use
  - Climate monitoring

SUSTAINABILITY

END STATE: An IT industry with a light carbon footprint that drives the reduction of carbon emissions throughout the global economy

HP LABS' RESEARCH CONTRIBUTION: Displace conventional supply chains with sustainable IT ecosystems

BIG BET:

SUSTAINABLE DATA CENTERS
Integrated, end-to-end management of compute, power & cooling resources from cradle to cradle

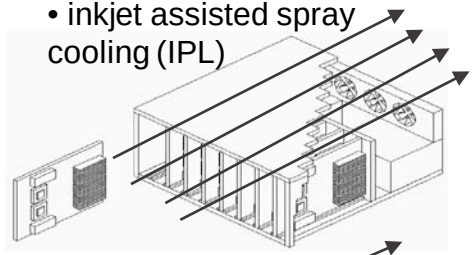
History of Work at HP Laboratories

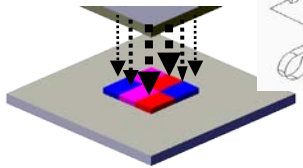
Thermal Management, Systems Design, Data Center Design and Management, Sustainable IT Ecosystem

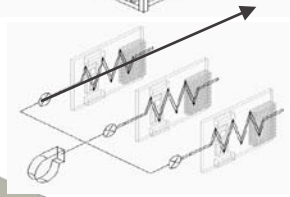
1991 **Chips & Systems** 1998 **Data Center** 2007 **Sustainable IT Ecosystem**

Efficient Management of Heat

- Thermo-mechanical design
  - K-class (1995) to C-class
- Highest heat transfer in the world at chip level
  - inkjet assisted spray cooling (IPL)

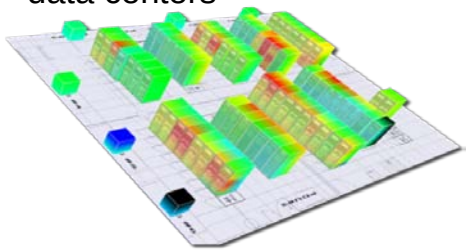


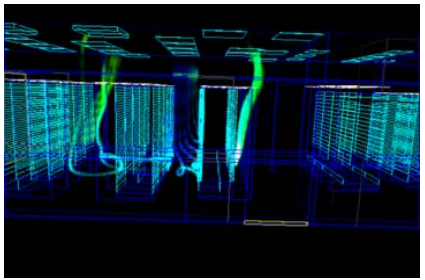




Demand side management

- Static and dynamic provisioning of power and cooling in servers and data centers

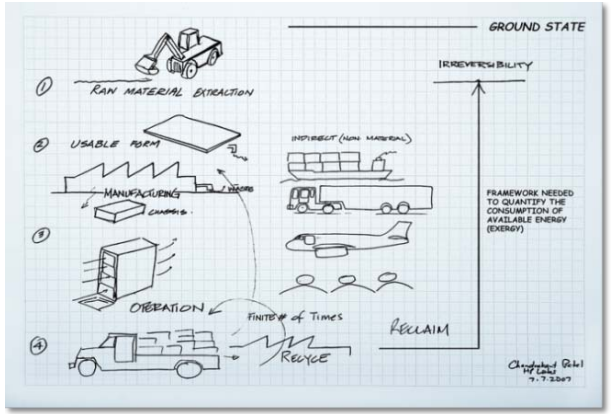




HP Thermal Assessment Service

Supply and Demand side management

- Cradle to Cradle Assessment Toolkit
  - *From component to corporation*
- Ecosystem level resource management over the lifecycle



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On building a Sustainable Data Center

End to end supply and demand side management

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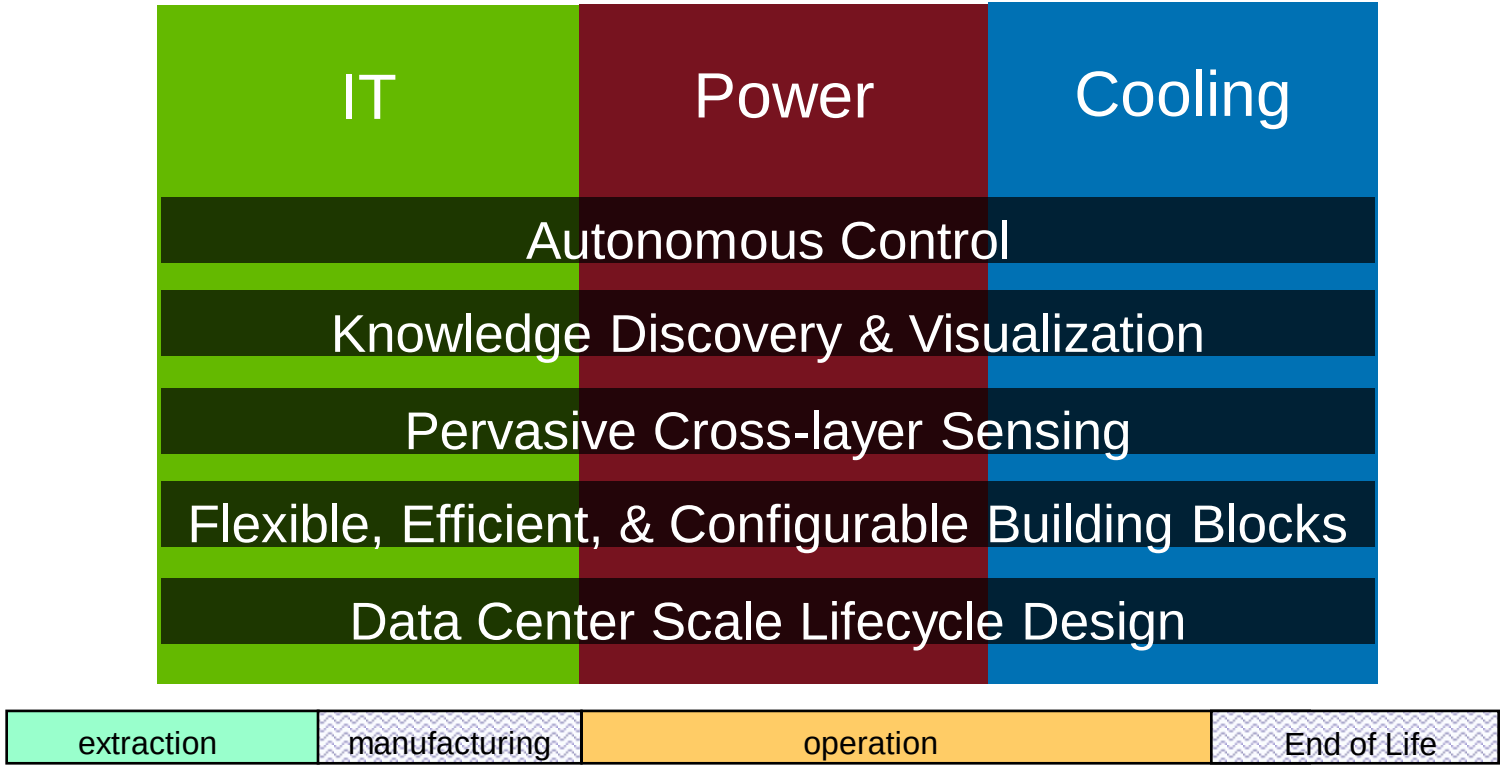
Sustainable Data Center

Key Components and Key Elements



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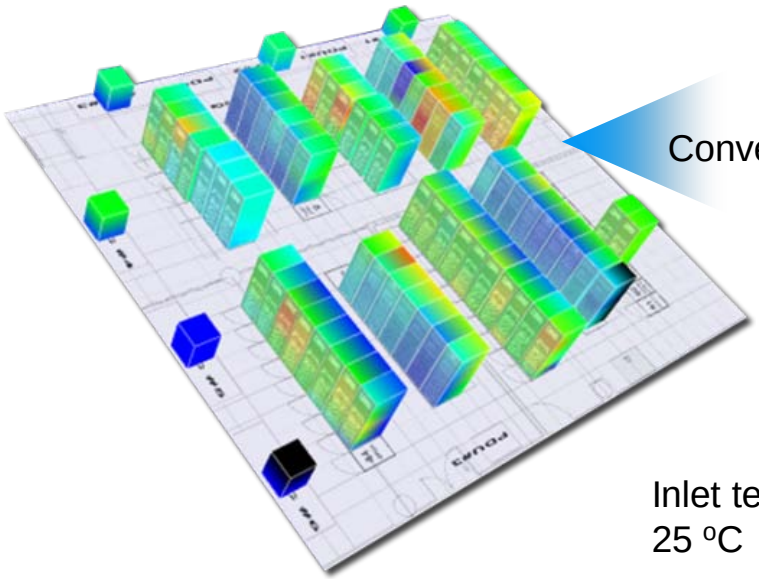
Dynamic Control of Cooling

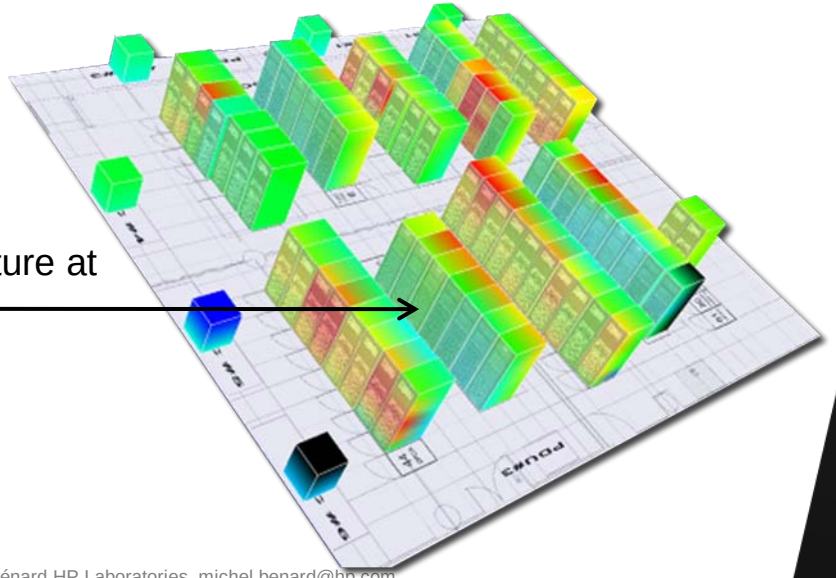
HP Labs Data Center, Palo Alto, CA

- Minimizing thermodynamic work by operating at higher temperature
- Minimizing flow work by “right” provisioning the fluid flow



Conventional approach

Inlet temperature at 25 °C



35% Available Energy Savings

Dynamic Control air flow rate and temperature

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Sustainable Data Center in HP Labs Palo Alto

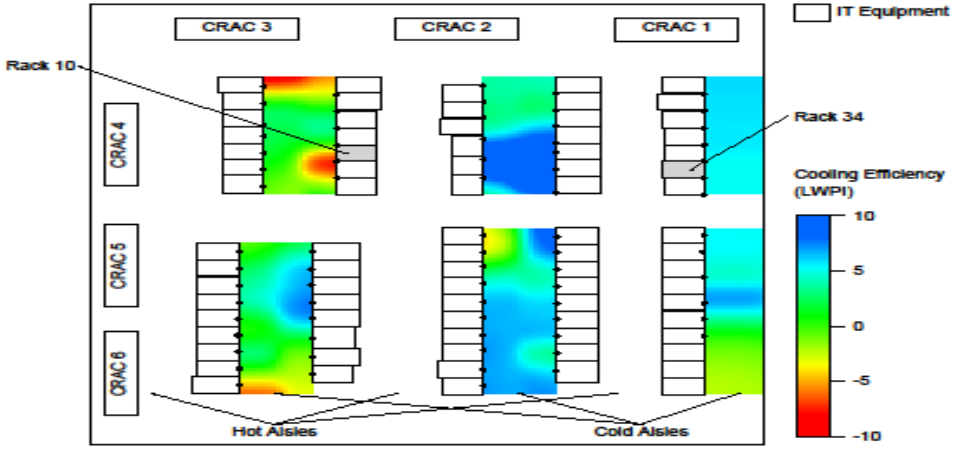
Efficient and light through dynamic allocation of power, compute and cooling resources

Research: Integrated IT-Facility Management

E Experiment setup :

- 20 physical servers
  - 9 in Rack 10; 11 in Rack 34
- 35 Virtual Machines
  - 2 interactive 3-tier apps
  - 29 computational workloads
- 10 hour experiment
- Integrated controllers
  - Application Controller
  - Node Controller
  - Pod Controller
  - DSC Controller

Example: Real-time thermal-aware placement of virtualized IT load



Savings: 26.5% IT power, 16.5% cooling power

EXTRACTION | MANUFACTURING | OPERATION | END OF LIFE

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Knowledge Discovery

Inference from thousands of sensed points

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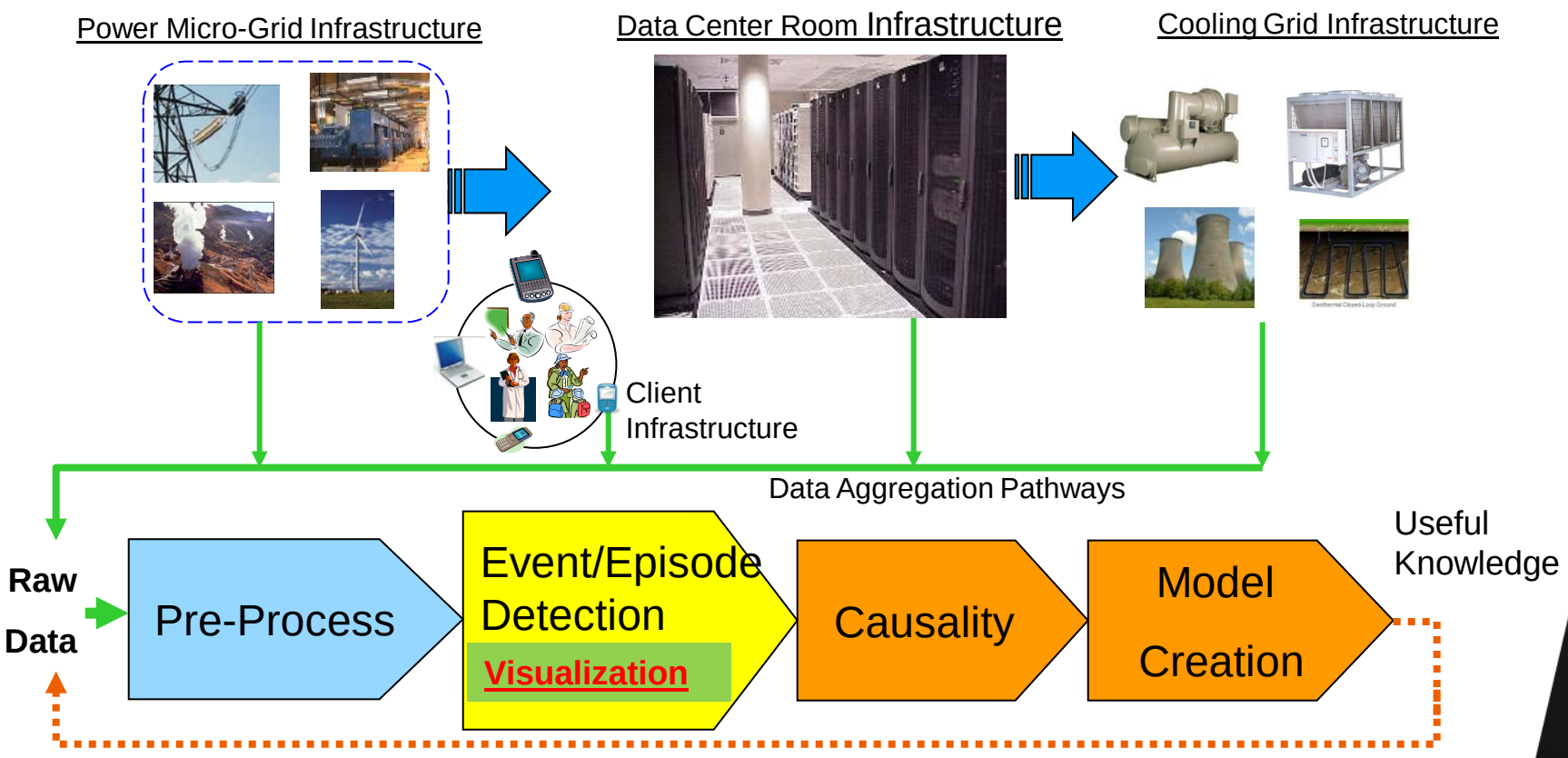
Knowledge Discovery



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Vindhyas – Asia Pacific Lab Data Center, Bangalore, India

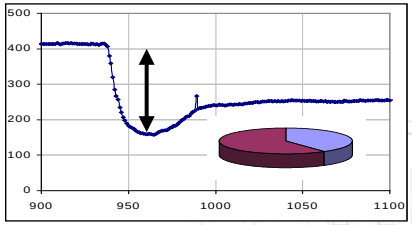
Facility Building Blocks

- **Chillers**
  - 3 air-cooled
  - 2 water-cooled

- **Pumps**
  - 7 Primary
  - 5 Secondary

- **CRAC units**
  - 55 units

- **Diesel Generators**
  - 5 3MW units



40% reduction in AHU power
20% reduction in Infrastructure Power
7,500 tons of CO_2 prevented annually

- Software Operations, Bangalore
- Consolidation of 14 lab data centers

IT Building Blocks

- Sensor Network
  - 7500 sensors
  - 10 second sample interval

- Dynamic cooling control implemented
- Data Analysis, Visualization and Knowledge Discovery to detect anomalies, improve reliability and minimize redundancy

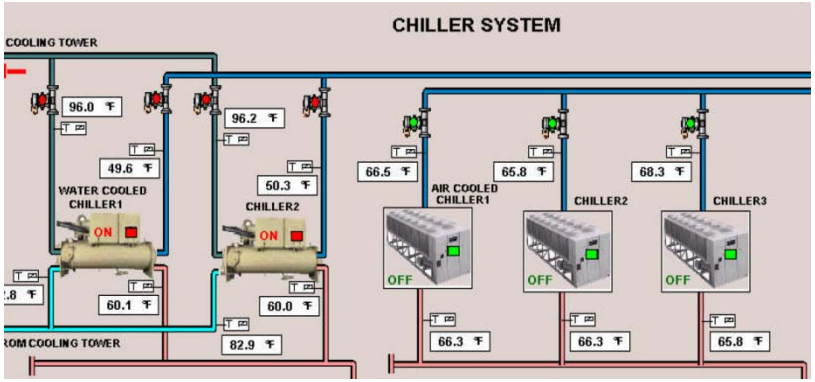
Example of Knowledge Discovery

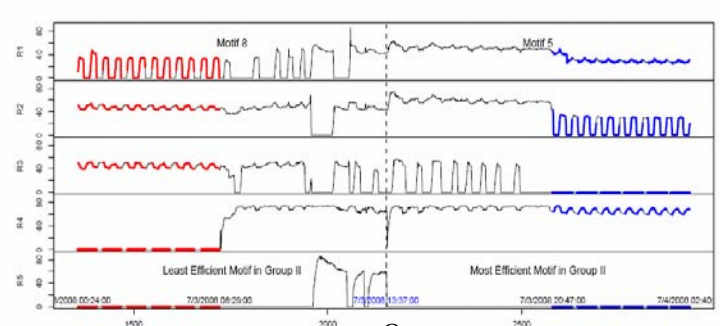
Pattern mining of chiller ensemble in Bangalore data center

Research: Motif mining, Anomaly Detection, Visual Analytics (HP Data Center Mobile Studio)

Focus on: Operational energy, emission, consumption of water and reliability

Example: Motif Mining applied to water and air cooled chiller ensemble





$$COP_G = \frac{Q_{dc}}{\sum_k \left(\sum_j \left(\sum_i \left(W_{cp} + W_{\sup-dev} \right) \right) + W_r \right) + \sum_l W_{b-cr} + \sum_m W_p + W_{comp} + W_{ct}}$$

Annual Savings: 359 MWh (~10%); 179,580 G direct water; 287, 328 Kg CO_2

EXTRACTION | MANUFACTURING | OPERATION | END OF LIFE

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Research on the Supply side

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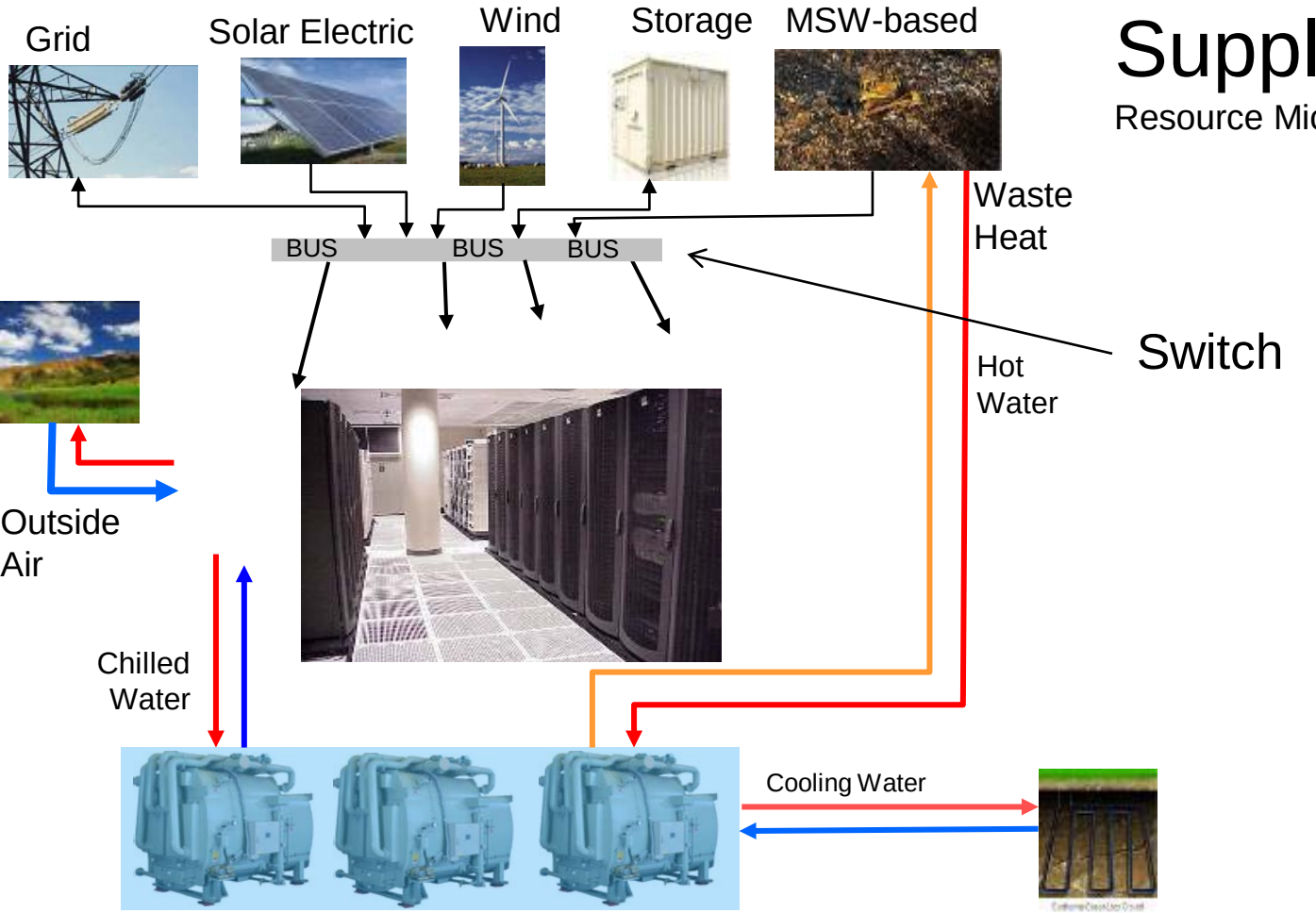
Supply Side

Resource Microgrids



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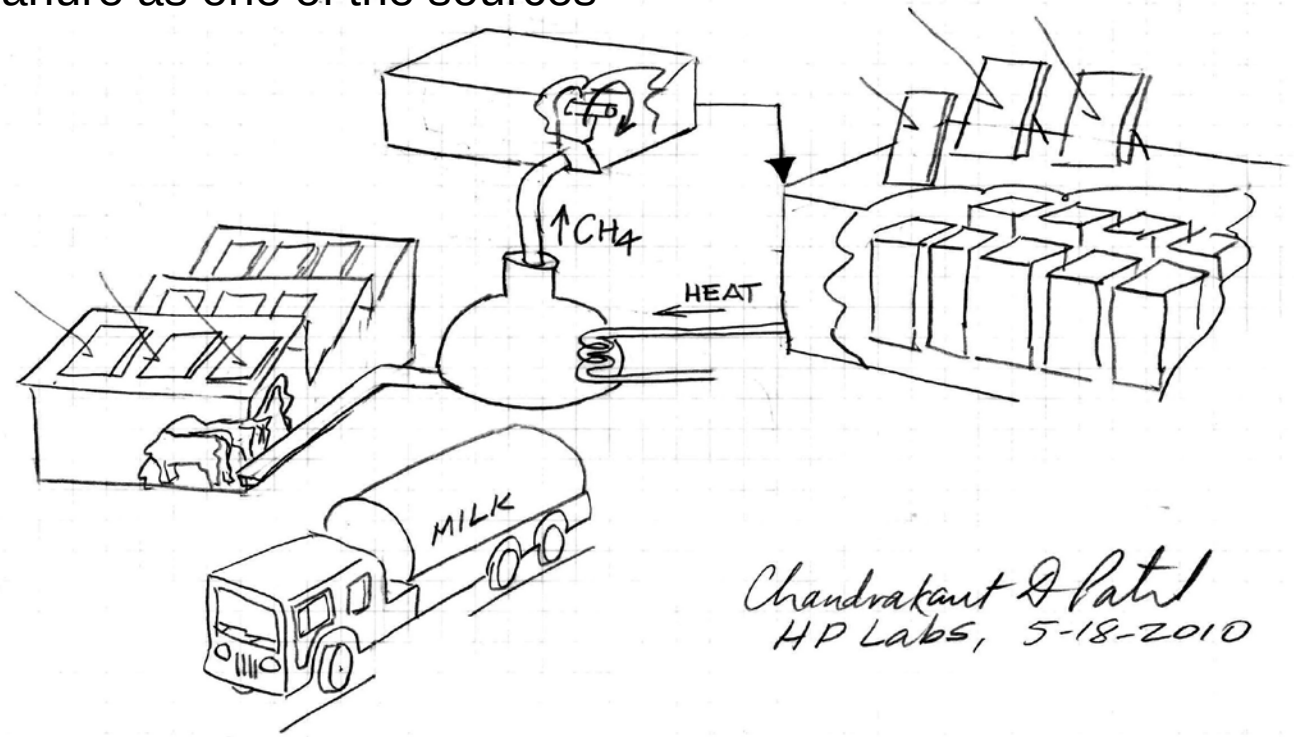
Supply Side Research

Manure as one of the sources



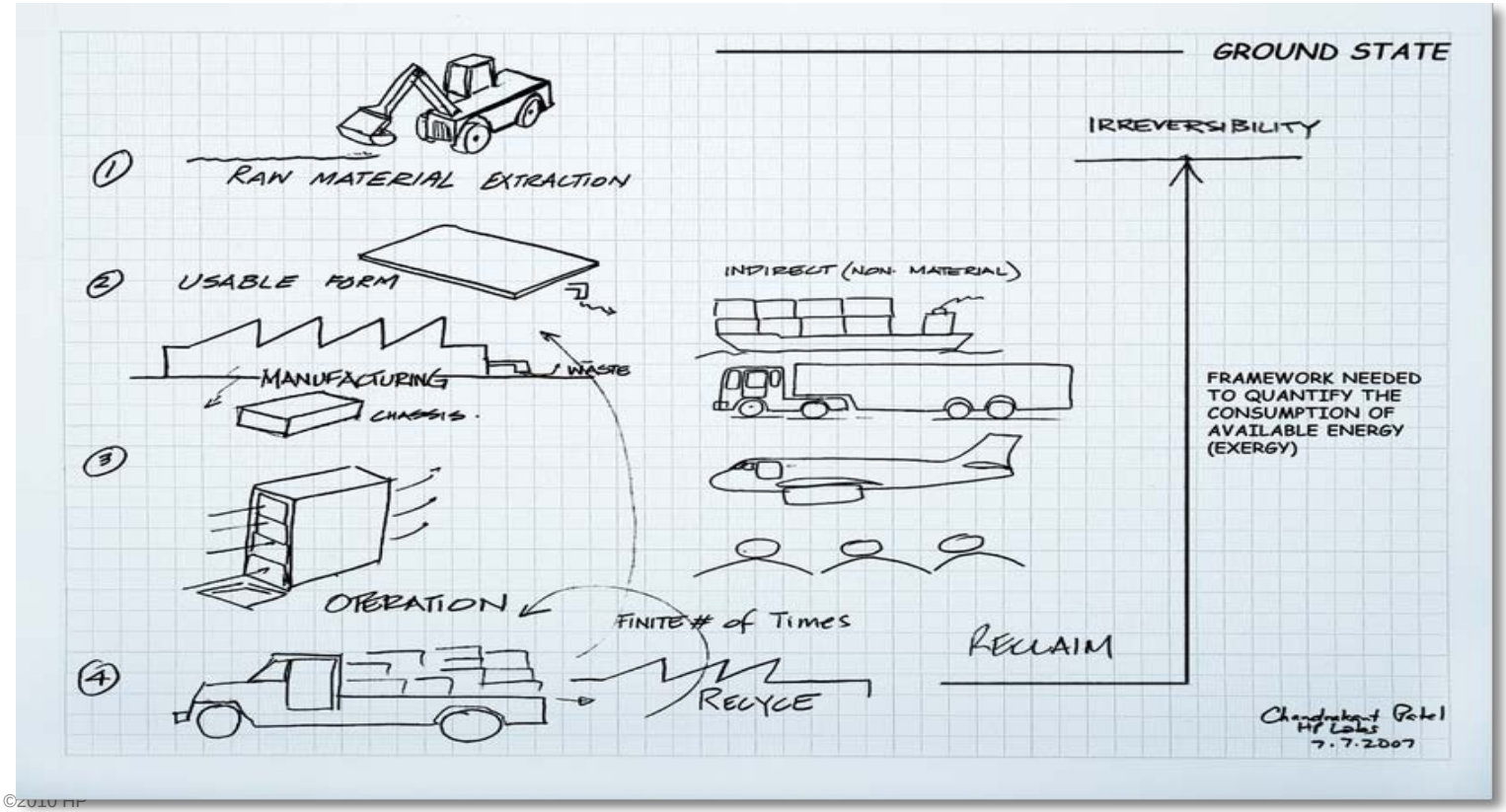
Server Farm at a Dairy Farm+ Micro-grid

Ref: Ratnesh Sharma, Tom Christian, Martin Arlitt, Cullen Bash, Chandrakant Patel, “Design of Farm Waste-Supply Side Infrastructure for Data Centers, ASME 2010-Energy Sustainability, ES 2010-90219

Supply Side Lifecycle Perspective

Lifecycle engineering and management

extraction	manufacturing	operation	End of Life



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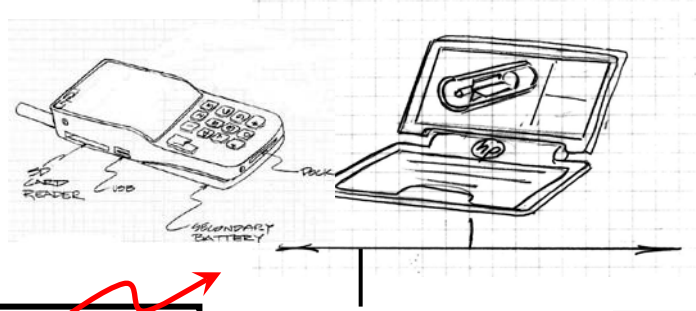
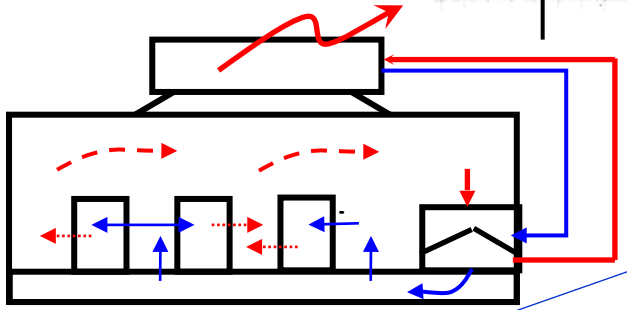
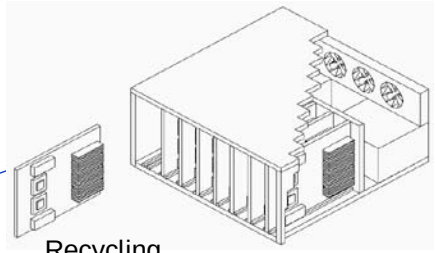
Lifecycle Footprint

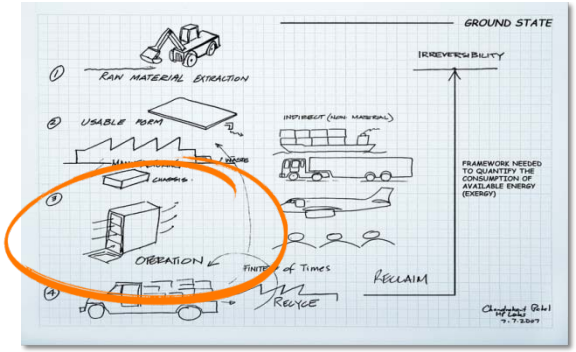


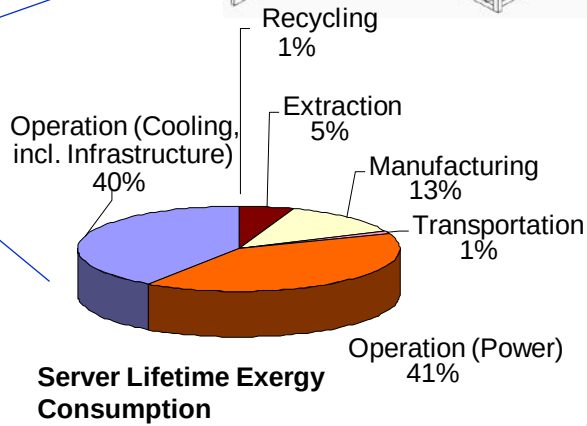
Embedded is 70%

Operational dominates









Server Lifetime Exergy Consumption

Hannemann, C., et. al., "Lifetime Exergy Consumption as a Sustainability Metric for Enterprise Servers", Proceedings of ASME Energy Sustainability, August 2008

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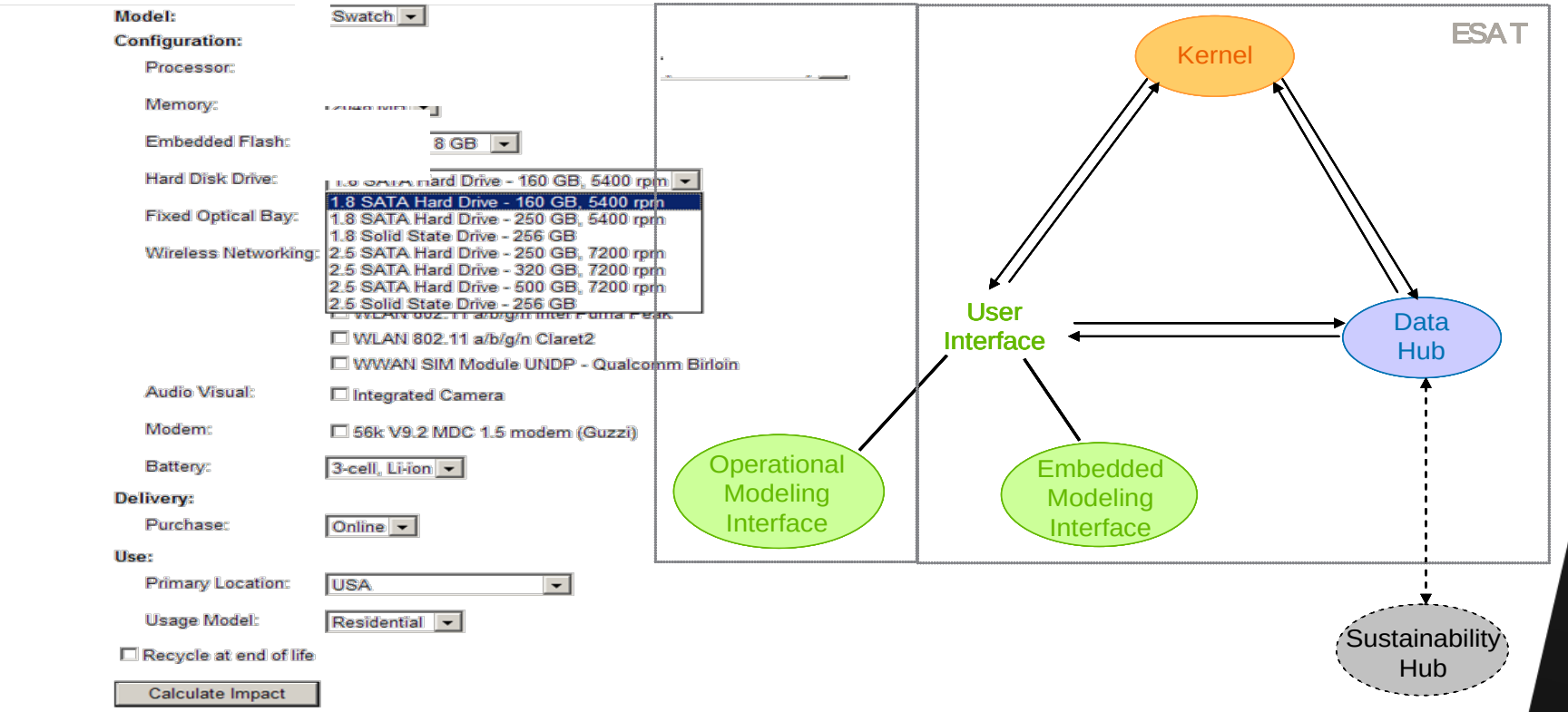
Environmental Sustainability Analysis Tool

Proactive design time approach, not compliance time



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On the Sustainable IT Ecosystem

Demand & Supply Management

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Role of the IT Ecosystem

addressing the fundamental needs of the society

1. **IT services to meet the fundamental needs of the masses**
   - *Advantage of scale when billions utilize IT to address their fundamental needs and improve quality of life*
   - Transformation necessitates
     - Reducing the cost of IT for universal accessibility
       - Reducing total cost of ownership necessitates addressing sustainability with an *end to end supply and demand side perspective*

Micro-businesses

2. **Use the IT ecosystem to enable need based provisioning of resources across all ecosystem**
   - Power, water, transport, waste…..
   - Transformation necessitates
     - *supply and demand side management of resources*

Queue at CNG Filling Station

Key Enablers:
- *Unifying Metric, Return to Fundamentals of Engineering & Multidisciplinary Curriculum*

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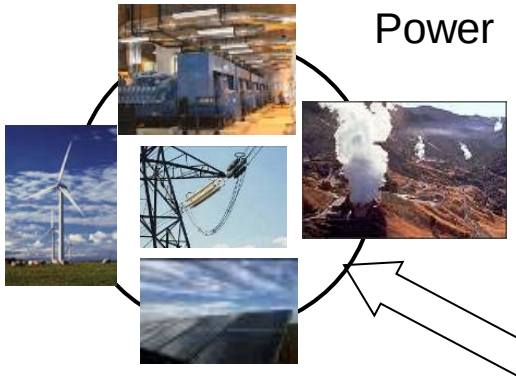
Data Center at the Core

Resource management at community scale

Power



TCO reduction through holistic supply and demand side perspective

Sustainable Datacenter

Healthcare

Ecosystem of Clients

Education

Water

Transport

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Technical Approach

Integrated Supply-Demand Management based on Service Level Agreement

- **Supply Side**:
  - Lifecycle perspective
    - available energy (exergy) required in extraction, manufacturing, operation and reclamation
  - utilize local resources to minimize destruction of available energy in transmission, construction of transmission infrastructure, etc
- **Demand Side**:
  - Provision resources based on the needs of the user
    - pervasive sensing, communications, knowledge discovery, and policy based control

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application to other ecosystems……

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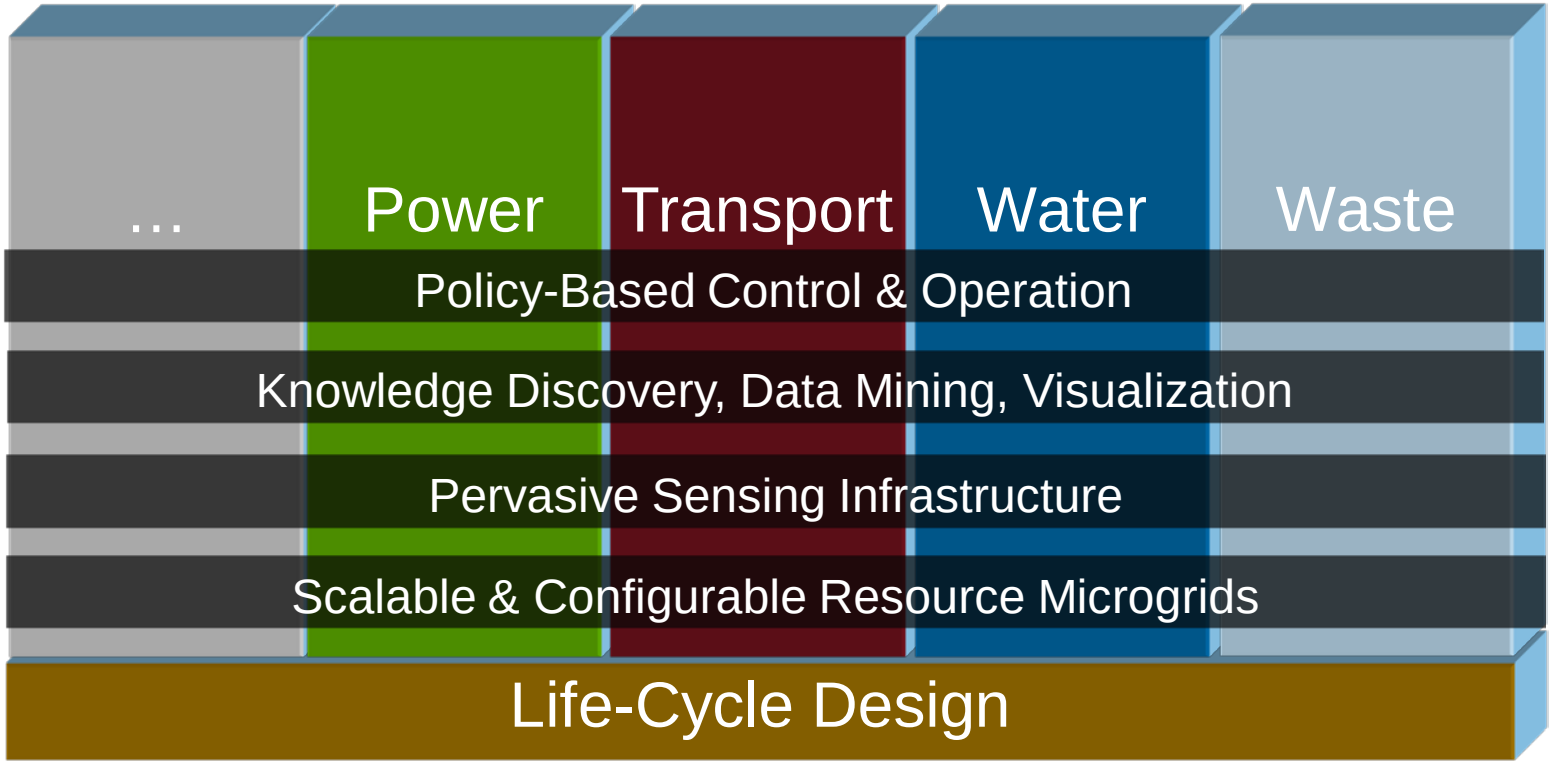
Sustainable Campus, District or City

Enabled by a Sustainable IT Ecosystem



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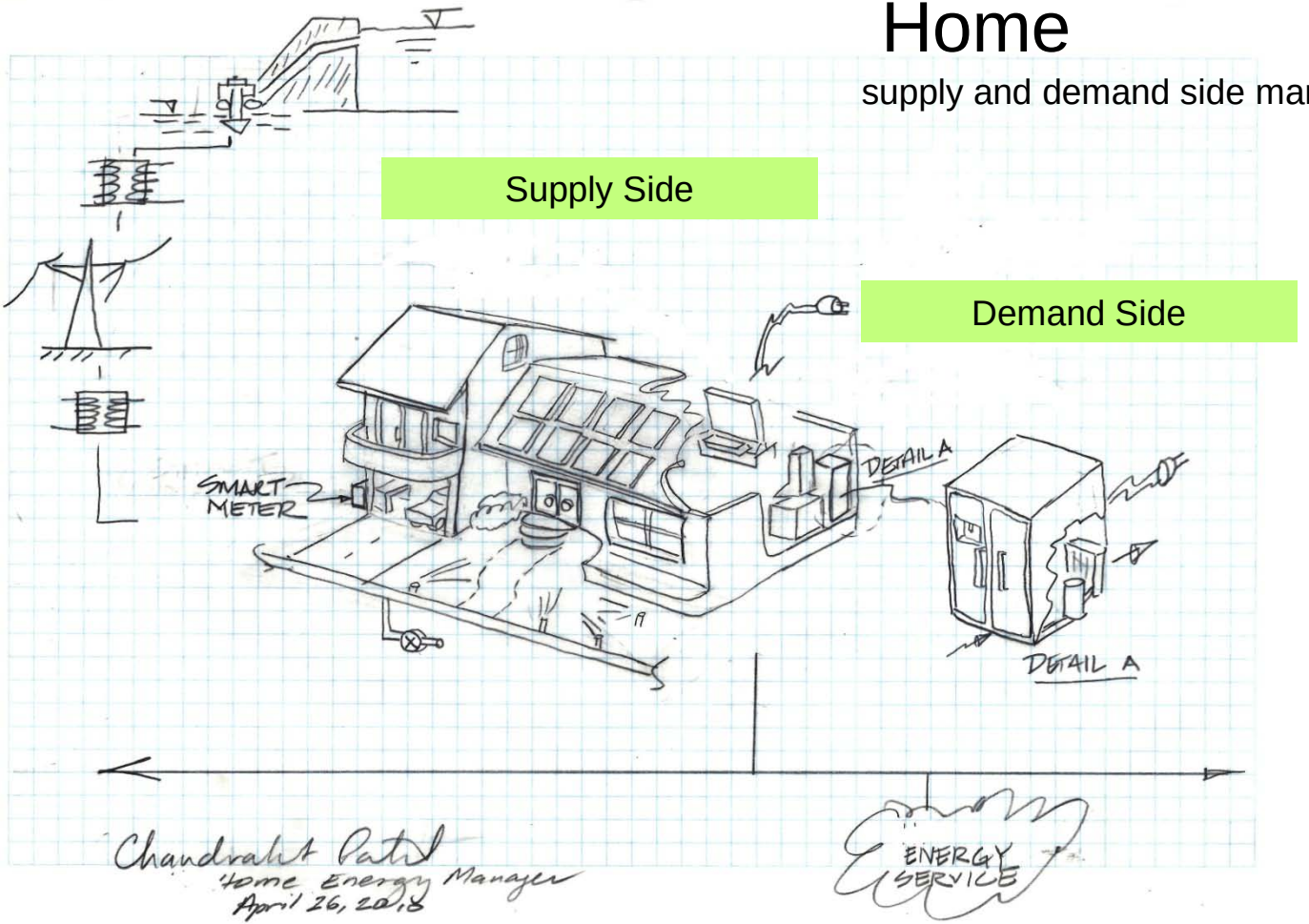
Home

supply and demand side management – SMART GRID



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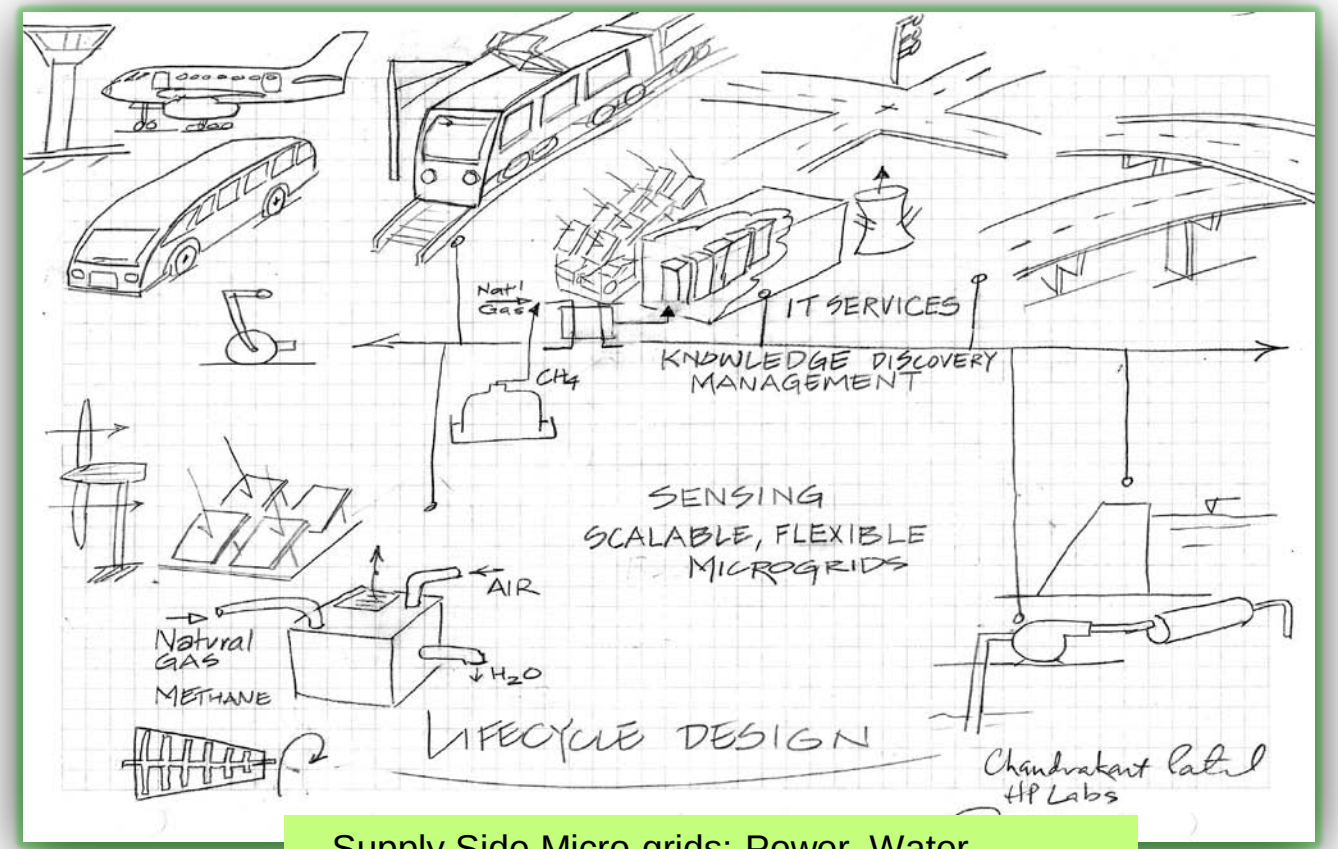
City

supply-demand side management of resources



Supply Side Micro-grids: Power, Water…….

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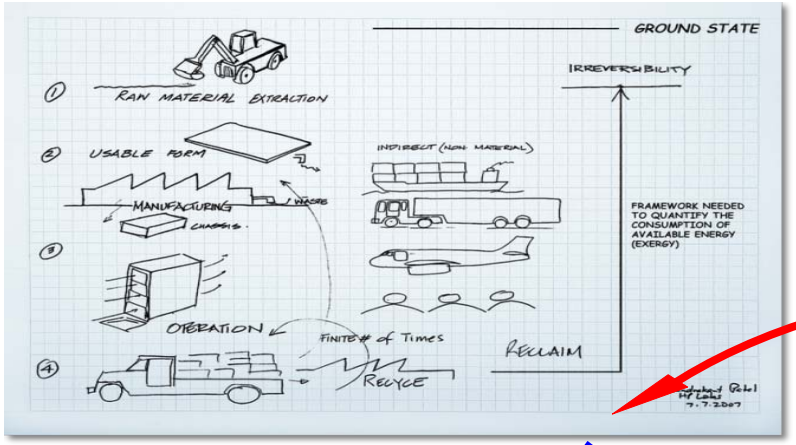
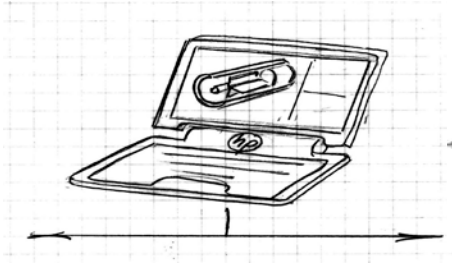
Joules: Currency of the flat world

in the cloud...

Joules of exergy destroyed per transaction?





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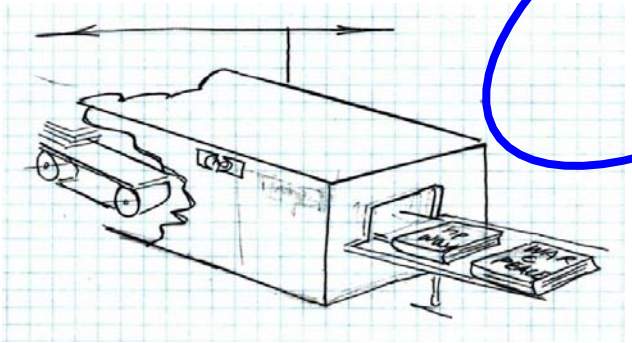

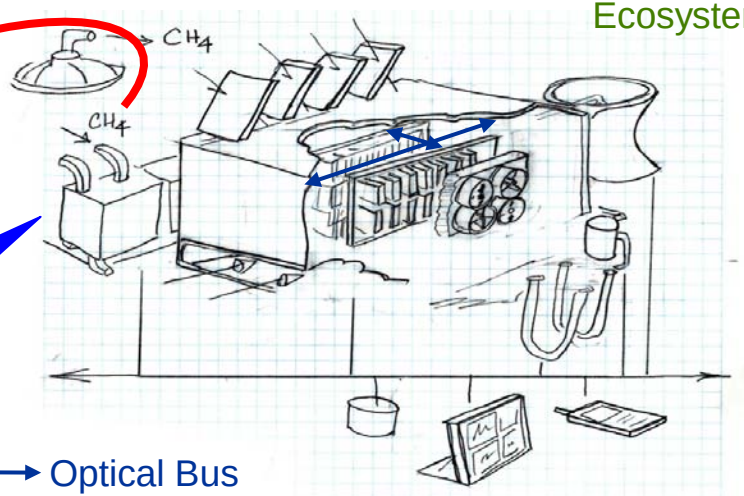

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