Green Data Centers: The European Sky
Key concern in Europe

• EU climate and energy package
  – 20-20-20 targets
    • A 20% reduction in EU greenhouse gas emissions from 1990 levels;
    • Raising the share of EU energy consumption produced from renewable resources to 20%;
    • A 20% improvement in the EU’s energy efficiency.
• Europe 2020 strategy for smart, sustainable and inclusive growth.
• Key concerns for employment:
  – 20% renewable energy target could create 417,000 additional jobs
  – 20% energy efficiency improvement would create 400,000 new jobs.
• Energy Efficiency Plan 2011
• Energy Efficiency Directive
1st Generation

- **FIT4Green**: Federated IT for a sustainable environmental impact (2009-2012)
  - Energy-aware layer of plugins for data center automation frameworks
    - Smart allocation of VMs in DC (consolidation)
    - Smart management of resources (on/off)
    - Cooperation between Data Centers

- **GAMES**: Green Active Management of Energy in IT Service centres (2010-2012)
  - Improve the design and management of DC
    - Methodology
    - Energy Sensing and Monitoring Infrastructure (metrics)
    - Autonomic Runtime
      - Local runtime
      - Global runtime
2nd Generation

- **All4Green**: Active collaboration in data centre ecosystem to reduce energy consumption and GHG emissions
  - [http://www.all4green-project.eu](http://www.all4green-project.eu)
  - 2011-2014

- **CoolEmAll**: Platform for optimising the design and operation of modular configurable IT infrastructures and facilities with resource-efficient cooling
  - [http://www.coolemall.eu](http://www.coolemall.eu)
  - 2011-2014

- **ECO2Clouds**: Experimental Awareness of CO2 in Federated Cloud Sourcing
  - [http://www.eco2clouds.eu](http://www.eco2clouds.eu)
  - 2012-2014
• Simulation, Visualization and Decision Support Toolkit
• Complete workflow to evaluate DC + blueprints
  – Different platform
    • Simulation: CFD/Runtime
    • Real platform execution
  – Different evaluation tools
    • Metrics and Benchmarks
  – Different granularity levels
    • Data Center Efficiency Building Block
• Different scenarii
  • System policies
  • Application profiles
  • Scheduling policies
  • Placement of servers in a room
GreenSDA & GreenSLA

- Active collaboration in data centre ecosystem to reduce energy consumption and GHG emissions
- Add link between
  - Utilities
  - DC Operators
  - Users
- Green SLAs, Information related to Renewable energy
- Two ways real-time informations : Emissions, Energy, needs
- Adapts Data Center load to real production, helps using renewable energy by providing more depth to decisions
- Use local energy when available reduces transport overhead
- Smart strategies in Data Centers reduces peak load for utilities
GreenSDA & GreenSLA

Regulated by:

GreenSDA

Regulated by:

GreenSLA

EP
Reduce Energy Consumption

deficit

surplus

Collaboration Negotiation Compensation

Consume Extra Green Energy

DC
Pause Virtual Machines

Collaboration Negotiation Compensation

Start Delayed jobs

ITC

The compensation is related to cooperative attitude and the “real value” of the received “help”
• **Experimental Awareness of CO2 in Federated Cloud Sourcing**
  
• Raise awareness on eco-metrics at all levels to improve:
  
  – Application development
  
  – Application and services deployment

• **Eco-metrics**
  
  – Energy, CO₂ (real-time mix from electricity provider) : Collect, and expose them
  
  – Several layers : Infrastructure, VMs, applications, services (based on actual measurements)

• **Optimization and deployment models**
  
  – Requirement at the level of infrastructure to support Eco-metrics
  
  – Upgrade of cloud semantics/runtime is needed

• **Evaluate impact of decisions on eco-metrics + new smart decisions systems**
  
  – Demonstration platform : BonFIRE
  
  – Data analysis in clinical domain
  
  – Eels case study
  
  – e-business with services
ECO₂Clouds develops key metrics to express energy consumption and CO₂ footprint of Cloud Facilities and Cloud Applications for quantification of their environmental impact.

Create optimization and deployment models to generate configurations which reduce the environmental impact.

Propose and design innovative application deployment strategies for sustainable federated Cloud sourcing with support for adaptation mechanisms to running applications.

Validate the effectiveness of optimization and adaptation processes through application in FIRE Facilities.

Strategies for Energy Efficient and CO₂ Aware Cloud Applications
The (ideal) big picture
The big picture

- Common elements
  - Evaluation
  - Benchmarks
  - Metrics
  - Usecases
- Raising awareness
  - Users
  - DC Operators/Planers
  - Utilities
- Discussions started but
  - lack of common standards/metrics/test infrastructure
    - Hardware platform / Data Sets / Simulation tools
Data centerspecific Smart Cities projects
Data centerspecific Smart Cities projects

- 6 projects
  - DOLFIN : Data Centres Optimization for Energy-Efficient and Environmentally Friendly Internet
  - GENiC : Globally optimized ENergy efficient data Centres
  - GEYSER : Green networked Data Centres as Energy Prosumers in smart city environments
  - GreenDataNet : Designing and validating a new, system-level optimisation solution allowing urban data centres to radically improve their energy and environmental performance
  - RENEWIT : Advanced concepts and tools for renewable energy supply of IT Data Centres
  - DC4Cities : Environmentally sustainable data centres for Smart Cities
<table>
<thead>
<tr>
<th>Project</th>
<th>Initial Cost</th>
<th>Final Cost</th>
<th>Start Date</th>
<th>End Date</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>DOLFIN</td>
<td>4.3M€</td>
<td>2.7M€</td>
<td>Oct 2013</td>
<td>Sep 2016</td>
<td>9</td>
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<tr>
<td>GENiC</td>
<td>5.4M€</td>
<td>3.2M€</td>
<td>Oct 2013</td>
<td>Sep 2016</td>
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<tr>
<td>Geyser</td>
<td>5M€</td>
<td>3M€</td>
<td>Nov 2013</td>
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<tr>
<td>GreenDataNet</td>
<td>4.3M€</td>
<td>2.9M€</td>
<td>Sep 2013</td>
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<tr>
<td>Renewit</td>
<td>3.6M€</td>
<td>2.5M€</td>
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<td>Sep 2016</td>
<td>7</td>
</tr>
<tr>
<td>DC4Cities</td>
<td>4.9M€</td>
<td>3.5M€</td>
<td>Sep 2013</td>
<td>Feb 2016</td>
<td>10</td>
</tr>
</tbody>
</table>

- Objective FP7-ICT-2013.6.2:
  - Data Centres in an energy-efficient and environmentally friendly Internet
  - 20 M€ allocated, 18 spent
- Expected impacts
  - 80 % renewable energy
  - Quantifiable improvement using classical metric (PUE,CUE,WUE)
  - New market opportunities
**DOLFIN**

- Data Centres Optimization for Energy-Efficient and Environmentally Friendly Internet
- Key Idea: demand/response and energy stabilisation
- Data Center management system
  - Parametric energy consumption optimisation mechanisms (eCOM) and related optimization policies
  - Data Center SLA renegotiation process with multi-objectives: ICT and energy
  - Elastic SLAs taking into account dynamism of renewable energies (standardization)
- Expected experimental results
  - Management software to manage IT, power and cooling systems
  - Direct water-based cooling system of servers for heat reuse
GENiC

- **Globally optimized ENergy efficient data Centres** - GENiC
- Improve coordination and optimization of sensing and cooling, and scheduling
  - Multi-level approach: CPU, rack, DC level
  - Multi-level approach also for cooling: Adapt cooling effort to specific heat-points
    - Optimize chiller, air fans and server fans as a system
- Integration of renewable energy sources (RES)
  - Interoperability of generation, storage and heat recovery
  - Give feedback on installation and maintenance cost versus payback
- Complete system so integration between control systems
  - Computing, cooling, generation, energy storage, and waste heat recovery
- Integrated management and control platform for DC wide optimisation of energy consumption
  - The platform will include open interfaces, common data formats, control and optimisation functions and decision support
- Metrics: energy consumption, PUE, CUE, uptime.
GEYSER

- Network of Data Centers
  - Consuming Power (DC) and Cooling
  - Producing Computing, Heat
- Integration in the surroundings: smart city
  - Flexible supply/demand load and energy management
  - Geographical renewable energy supply-aware load balancing
- Synergetic IT infrastructure (computing, storage), cooling and power with fine grained monitoring and control
  - Computing, storage, cooling, power
- Key concept
  - Fluid (power, heat) flows are to be integrated along with smart cities
- Metrics
  - PUE below 1.20 and CUE and ERE improvement by 30% in average
  - Simulation-based lab trial
  - Real life one year validation in three operational data centres, partially powered by renewable energy
GreenDataNet

- Remote Smart Energy Management Tool (like DCIM)
  - Manage multiple Data Centers
  - Control the interaction between IT hardware, software and renewable energy sources.
- Green Data Center Network
  - Optimization of IT, power, cooling and storage
- For cooling, heat reuse and free cooling
  - Three levels: servers and racks, individual data centers, and networks of data centers
  - Integration of local photovoltaic energy
  - Storage based on used Li-ion car batteries
- Improvement of existing Data Centers
  - Addition of renewable energy, electricity storage
  - Improve P.U.E. from 1.8, 2.0 down to 1.3
- Metrics
  - PUE and new metrics for standardisation bodies like CEN/CENELEC/ETSI
- Demo on three sites, one of them with photovoltaic panels and integrated in a experimental smart-grid
• Advanced concepts and tools for RENEWable energy supply of IT Data Centres
• Web-based interface for simulation tool
  – Provide feedback with key metrics: carbon footprint
  – Uses meta-models from advanced dynamic simulation models
    • Management of the IT load following “green” objectives
    • Low-energy air-conditioning systems
    • Solar cooling
    • Interaction with district heating and cooling networks, re-use of heat
    • Optimal use of heat and cold storage, and integration in smart grids
    • Energy sources
    • Connection with city-wide smart-grid
  – Metrics from standardisation and industries bodies, other European projects
• Public
  – Planners, managers, investors, owners and designers of Dcs
• Evaluating the environmental performances of different technical solutions integrating RES taking into account climate
• Validation in collaboration with 8 Data Centers (4 in Northern and 4 in Southern Europe)
Dc4Cities

- DC4CITIES: Environmentally sustainable data centres for Smart Cities

- Two roles for smart cities
  - Key component to provide the smart in *smart-cities*
  - Energy black hole

- Dc4Cities
  - For old and new Data Centers
  - New metrics, benchmarks and measurement technologies, toward new standards
  - Energy-aware SLAs
  - Match load with locally produced renewable energy

- Create a set of action to adapt to external energy constraints
  - Connected to local Smart Grids and Micro Grids
  - Holistic scheduling policies
Renewable research

<table>
<thead>
<tr>
<th></th>
<th>Holistic Management</th>
<th>Multiple Data Centers</th>
<th>Middleware</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolfin</td>
<td>x</td>
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<td>x</td>
<td>SLAs</td>
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<tr>
<td>Genic</td>
<td>x</td>
<td></td>
<td>x</td>
<td>Open Software Platform</td>
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<td>Geyser</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Direct Current</td>
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<tr>
<td>GreenDataNet</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>Batteries</td>
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<tr>
<td>Renewit</td>
<td></td>
<td></td>
<td></td>
<td>Models</td>
</tr>
<tr>
<td>DC4cities</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>External interactions</td>
</tr>
</tbody>
</table>

- Similar projects
  - Lot of produced code/models/metrics
- European commission is energy-aware
  - Synchronization benchmarks are scheduled
Horizon2020

- Euro R&I funding programme (2014-2020)
- Strong focus on societal challenges
- EU policy objectives (climate, environment, energy, transport etc) cannot be achieved without innovation
  - Proposed funding

<table>
<thead>
<tr>
<th>Secure, clean and efficient energy</th>
<th>5 782 M€</th>
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</thead>
<tbody>
<tr>
<td>Smart, green and integrated transport</td>
<td>6 802 M€</td>
</tr>
<tr>
<td>Climate action, resource efficiency and raw materials</td>
<td>3 160 M€</td>
</tr>
</tbody>
</table>
Secure, clean and efficient energy
- Smart cities; Energy efficient buildings; smart electricity grids; smart metering;

Smart, green and integrated transport
- Smart transport equipment, infrastructures and services; innovative transport management systems; safety aspects

Climate action, resource efficiency and raw materials
- ICT for increased resource efficiency; earth observation and monitoring
H2020 : ICT in Societal Challenges

- Digital Agenda For Europe
  - Pillar V : Research and innovation
    - Action 120: Key Transformative Action: Establishment of the European Cloud Partnership to harness public buying power to accelerate the development of the market for cloud computing
    - Action 121: Follow up of the European Cloud Computing Strategy
    - Action 122: Launch pilot action to explore the efficiency gains from moving public services into the Cloud
    - Action 132: Invest in High Performance Computing
      - Public-Private Partnership