ORNL – LCCP: An extensible Framework for Life Cycle Climate Performance based Design of Energy Systems

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Emissions Due to HVAC&R

- Emissions occur throughout lifetime
  - Leakages, service & disposal
  - Operation
  - Manufacturing & transport
- Mitigation
  - Low/No GWP alternatives
  - Efficient recovery/reuse
  - Efficient systems
  - **Systems approach towards design**

Life Cycle Climate Performance

- Total CO2 equivalent global warming impact over total lifetime of the system
- Comprised of
  - Direct emissions: refrigerant released
  - Indirect emissions
    - Energy consumption over lifetime and recycling
    - Power input during operation, transport, processing
    - Manufacturing of systems/components, recycling
- Units: kg CO2 /kg OR CO2e

LCCP History

- ORNL
  - Life cycle analysis for alternative refrigerants
  - Total Equivalent Warming Impact (TEWI)
- Papasavva (1997)
  - Expanded TEWI to Life Cycle Warming Impact (LCWI)
- Andersen (1999)
  - Montreal Protocol, Technology & Economic Assessment Panel
  - Coined: Life Cycle Climate Performance (LCCP)

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LCCP Software Efforts

- GREEN-MAC LCCP (2004)
  - Automotive
  - Peer reviewed, contribution from 50 experts,
  - http://www.epa.gov/cppd/mac/
- AHRTI (2011)
  - October 2011, AHRTI Report No. 09003-01
  - Residential heat pumps
- ORNL – LCCP (2012)
  - Project at CEEE/UMD funded by DOE/ORNL

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AHRI LCCP

- ***Life Cycle Climate Performance Model for Residential Heat Pump Systems***
- Excel-based simulation tool for calculating the direct and indirect emissions for residential heat pump systems
- http://www.ahrinet.org/technical+results.aspx

Future Energy Systems

- Engineered for performance, cost,…, **LCCP**,…
- LCCP needs to be one of the design metric
- Should be one of the objectives or constraints during design optimization

Challenges

- Standardized LCCP calculation
- Bring diverse set of analysis tools onto a single platform – without exposing any IP
  - Can serve as a platform or component of a bigger platform
- System (refrigeration vs. A/c) independent
- Transparent calculations, peer-reviewed
- Input uncertainty
- Standardized outputs

ORNL LCCP Objectives

- **Design Tool**
- Build on existing methodologies
- Extensible framework for LCCP design
  - Can be coupled with existing system/load calculations tools
- Wide range of applications
  - Supermarket refrigeration, heat pumps,…
- Desktop and Web/Cloud based interfaces
- Open Source

LCCP

Direct Emissions

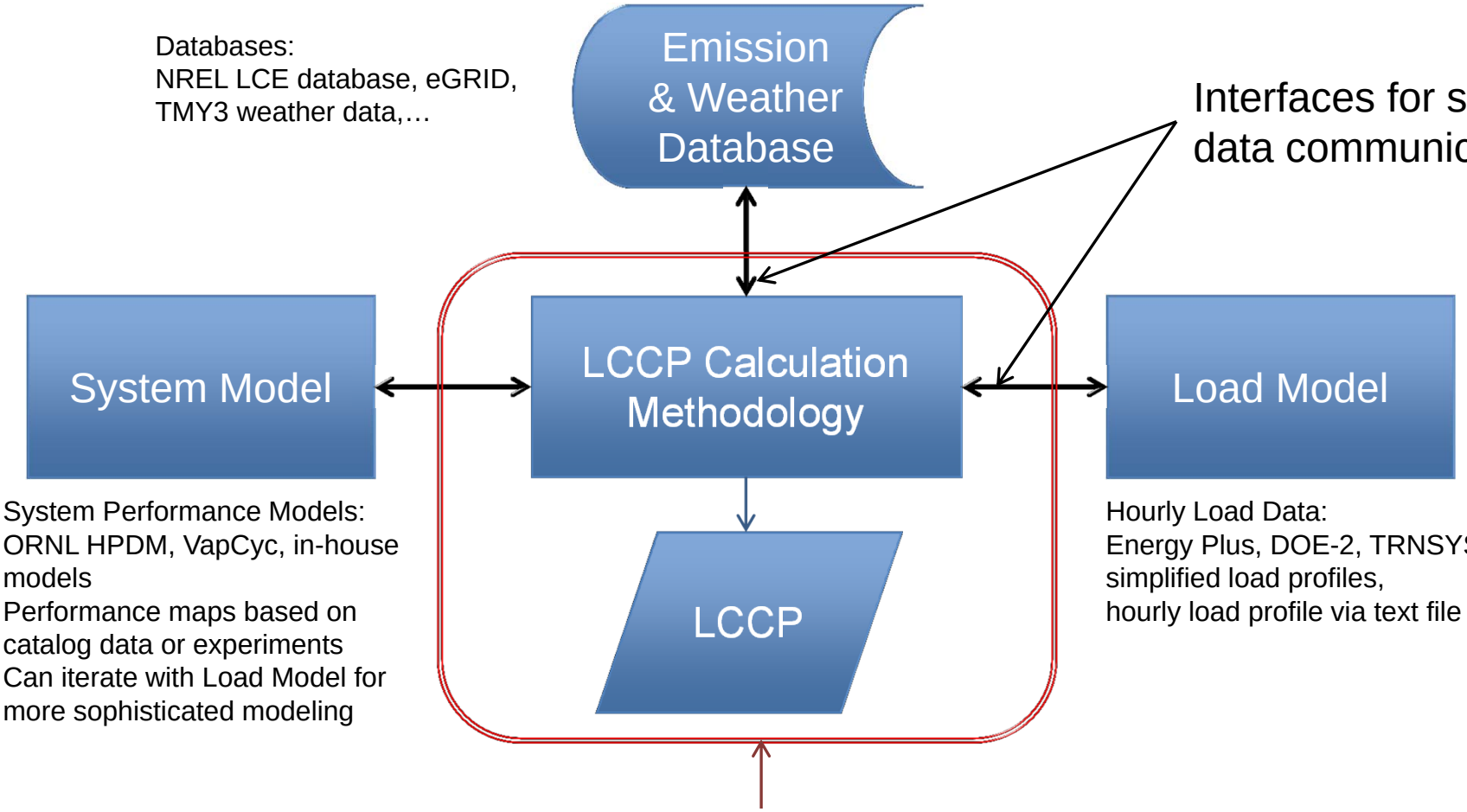
- Regular emissions
- Irregular emissions
- Service emissions
- End-of-life emission
- Leakage during production & transport

Indirect Emissions

- Energy consumption of the system
- Energy to make system/components
- Energy to produce refrigerant
- Energy to transport
- Energy for end-of-life, recycling/recovery of system and refrigerant

* Also included are place-holders for user-defined emissions

ORNL LCCP Framework



Components will be developed as “Open Source”.
Other components can be open-source or proprietary

LCCP Inputs

- System
  - Lifetime, leak rates, service intervals, power consumption, charge,..
- Refrigerant
  - GWP, manufacturing, transport, leakage, recycling energy
- Components
  - Manufacturing, transport, recycling
- Application
  - Weather, power-plant emissions, renewable factor

* Also included are place-holders for user-defined inputs

Role of System Simulation Tool

- Indirect emissions: 40%-80% of total
- LCCP approach involves hourly energy consumption calculations, 8760 evaluations
- Robust system simulation tool
  - For novel systems
  - Fast & flexible
  - Allow system design/optimization with LCCP as one of the criterion

ORNL LCCP Web App

- http://lccp.umd.edu/ornllccp/
- Simplified application for evaluating LCCP of supermarket refrigeration systems
- Commonly used medium and low temperature applications
- Pre-defined cities and load profile(s)

ORNL LCCP Desktop App

- System
  - VapCyc based
    - Interchange component models
    - Refrigerant mixtures
    - User-defined components and fluids
  - User-defined
- Loads
  - Text file
  - EnergyPlus
  - User defined

Future Directions

- First public BETA available in Sep 2012
- Demonstrate integration with other popular simulation tools
- Refine calculation methods
  - Request for public comments
- Add support for Air-Source Heat Pumps
- Uncertainty/Sensitivity Analysis

LCCP Desktop Version Demo

Project Team

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Thank You