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Organisation intergouvernementale pour le développement du froid

INTERNATIONAL INSTITUTE OF REFRIGERATION
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Review of Life Cycle Climate Performance Analysis and IIR Working Party

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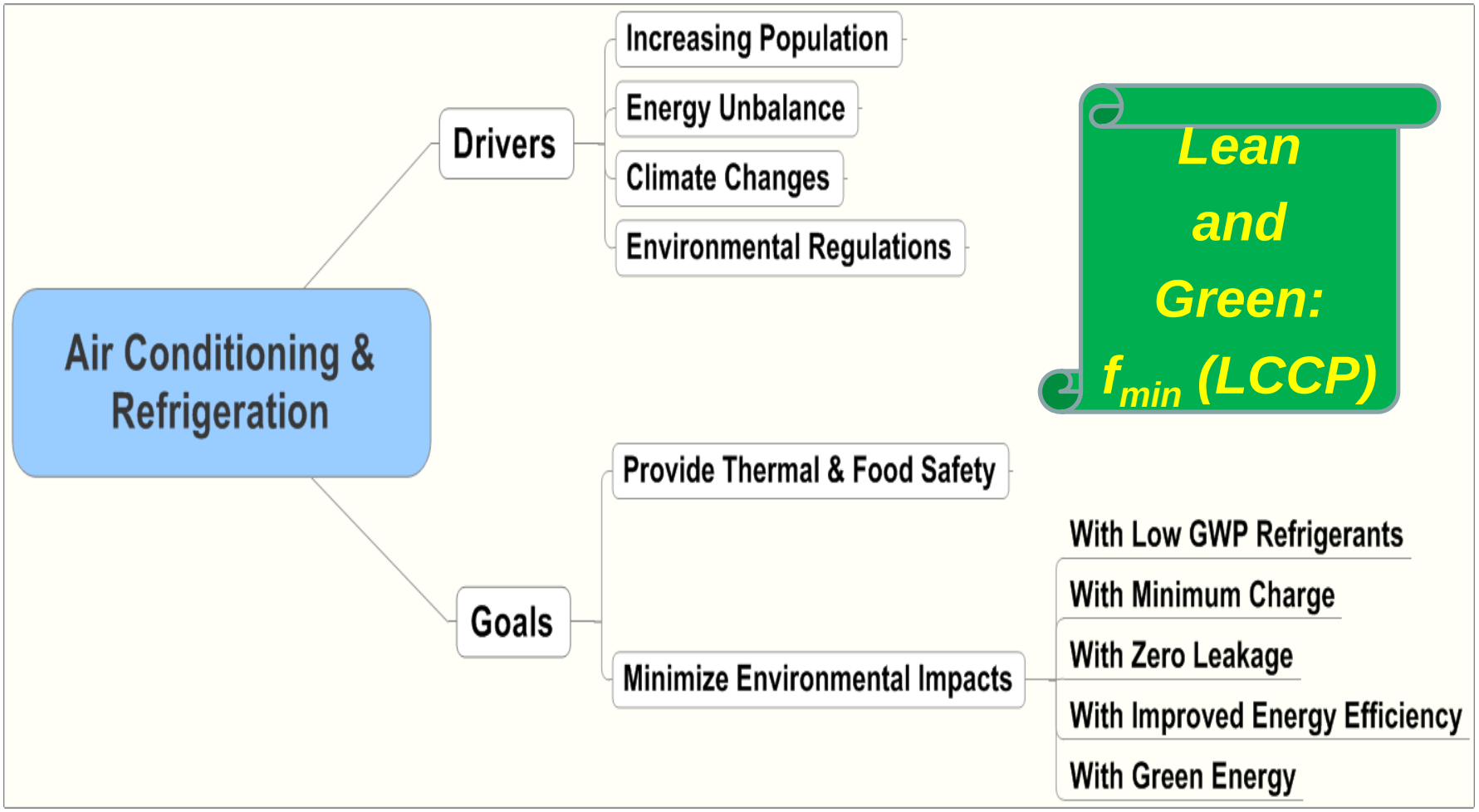
IIR Working Party: Life Cycle Climate Performance Evaluation

Introduction

- The **Center for Environmental Energy Engineering (CEEE)**, is a leader in research and education in environmentally responsible, economically feasible integrated energy conversion systems for buildings and transportation. Research focuses in particular on air-conditioning, refrigeration and heat pumping and integrated cooling heating and power systems.
- The **International Institute of Refrigeration (IIR)** is the only independent intergovernmental science and technology based organization which promotes knowledge of all refrigeration fields from cryogenics to air conditioning, including liquefied gas, the cold chain, refrigeration processes and equipment, refrigerants and heat pumps.

Introduction



Introduction: Env. Index History

- ORNL (1991)
  - 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)

Introduction: Env. Index

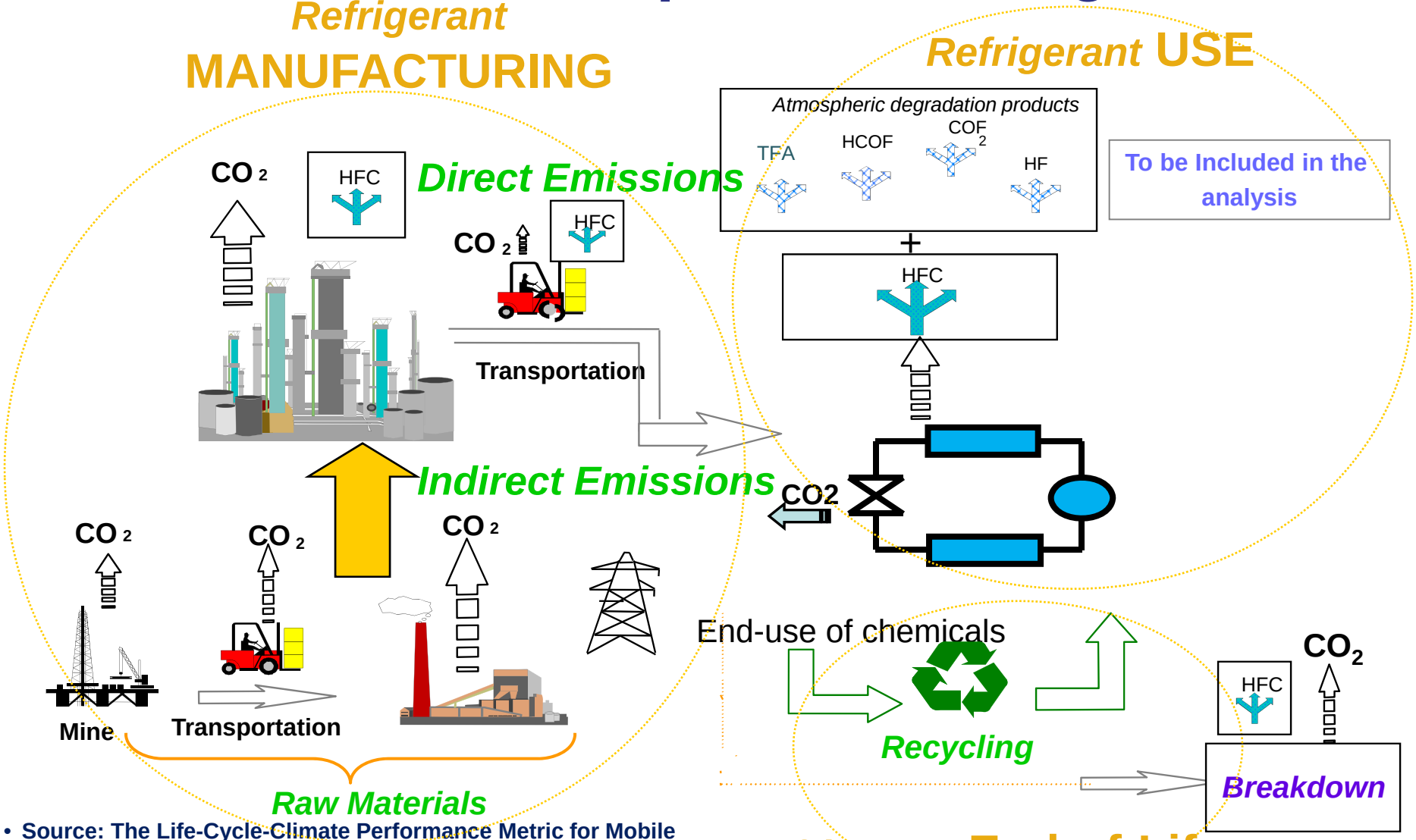
- **Total Equivalent Warming Impact (TEWI)**
  - Uses CO_2 as a baseline for comparison
  - Useful for comparing relative global warming impacts of alternative refrigerants under controlled assumptions
  - Numerous assumptions

TEWI = GWP (direct) + GWP (indirect)

- **Life Cycle Climate Performance (LCCP)**
  - Rigorous approach to identifying and quantifying direct and indirect environmental impact

LCCP = TEWI + *GWP (Indirect)* [energy consumption expressed as CO_2-eq emissions from chemical production & transport, manufacturing components & vehicle assembly and end-of-life] + ***GWP (direct)*** [chemical refrigerant emissions including atmospheric reaction products, manufacturing leakage, and end-of-life]

Environmental Impacts of Refrigerants



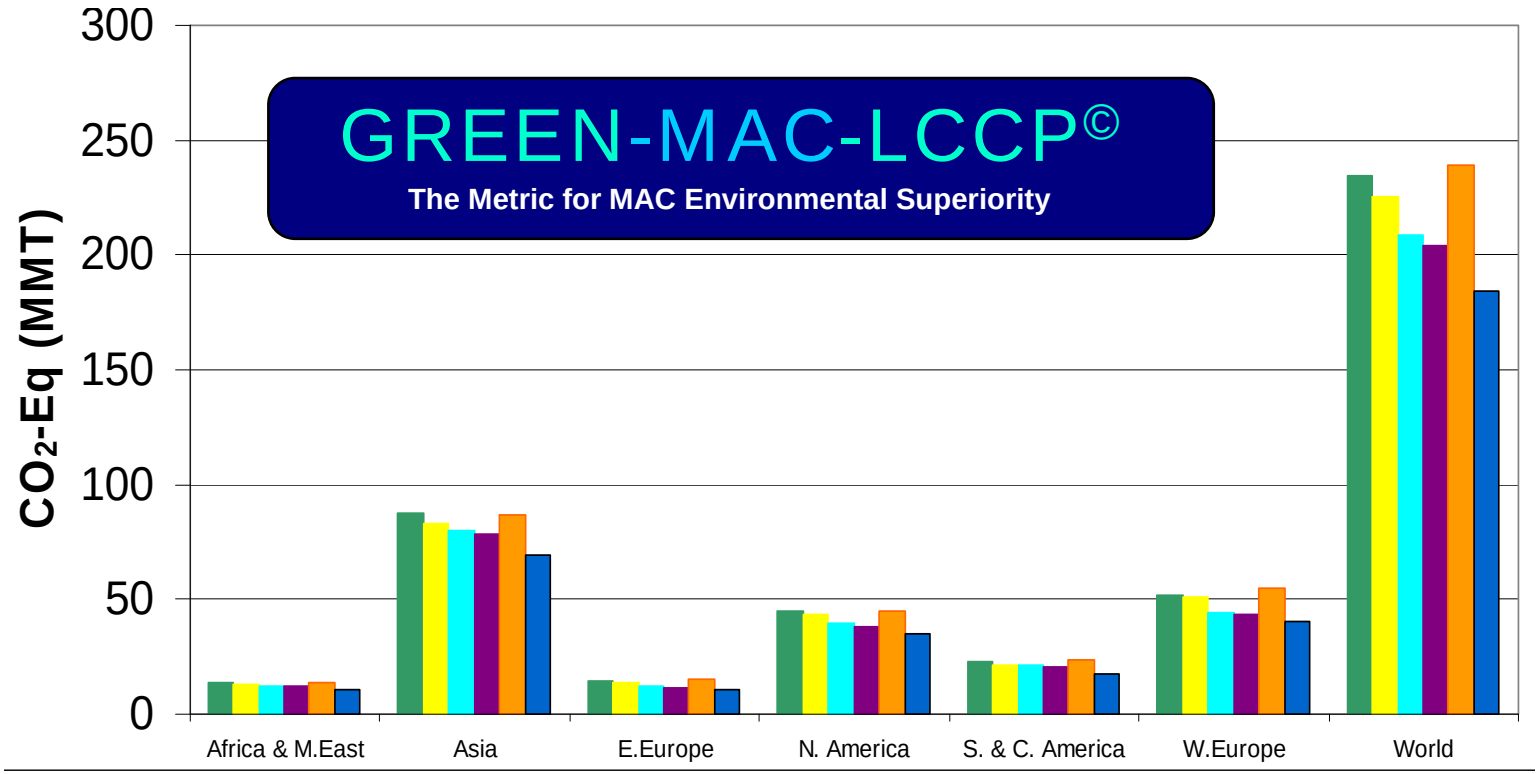
- Source: The Life-Cycle-Climate Performance Metric for Mobile Air Conditioning Technology Choice, Stella Papasavva and Stephen O. Andersen, Environmental Progress and Sustainable Energy Journal, Vol. 30, 2010.

Introduction

- **Life Cycle Climate Performance**
  - **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**

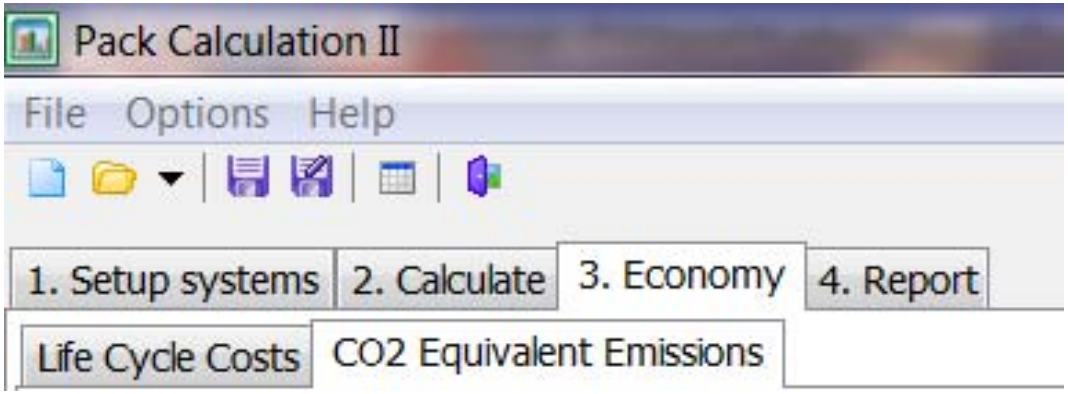
Tools Available

- **GREEN-MAC LCCP (2004)**
- **Automotive Peer reviewed, contribution from 50 experts.**

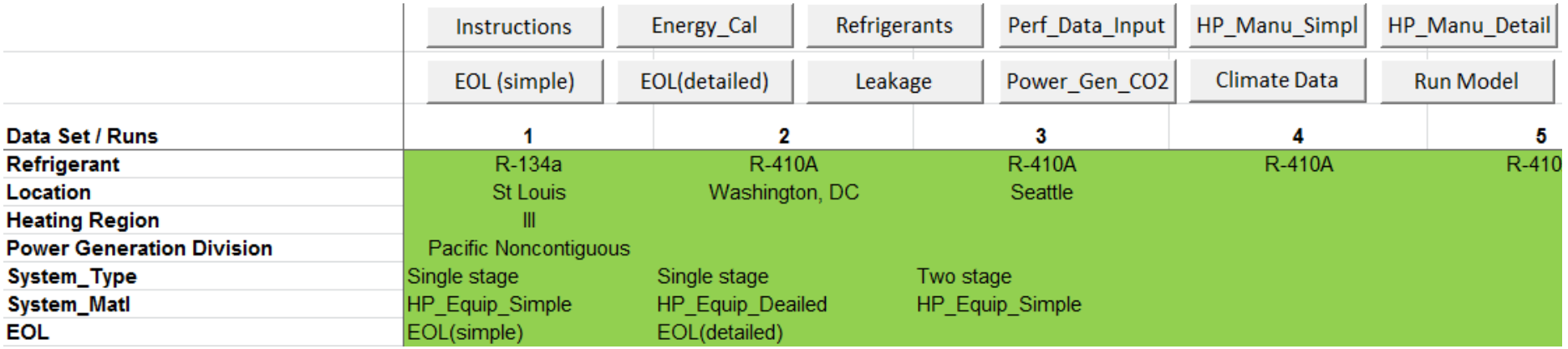


Tools Available

- **IPU's Pack Calculation II for TEWI and LCC**



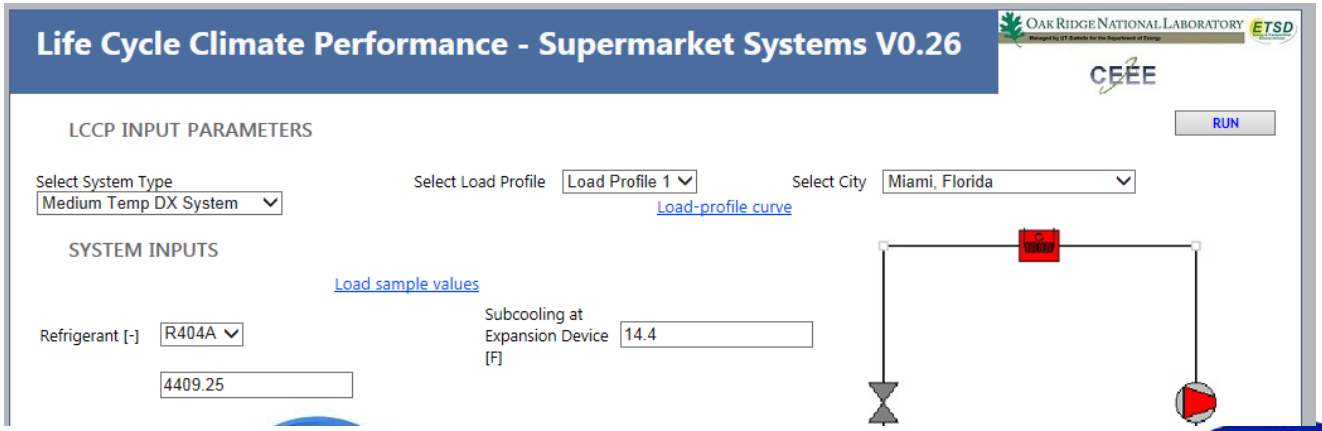
- **AHRTI's Residential HP LCCP (2011) – Excel**



Data Set / Runs	1	2	3	4	5
Refrigerant	R-134a	R-410A	R-410A	R-410A	R-410
Location	St Louis	Washington, DC	Seattle		
Heating Region	III				
Power Generation Division	Pacific Noncontiguous				
System_Type	Single stage	Single stage	Two stage		
System_Matl	HP_Equip_Simple	HP_Equip_Deailed	HP_Equip_Simple		
EOL	EOL(simple)	EOL(detailed)			

Tools Available

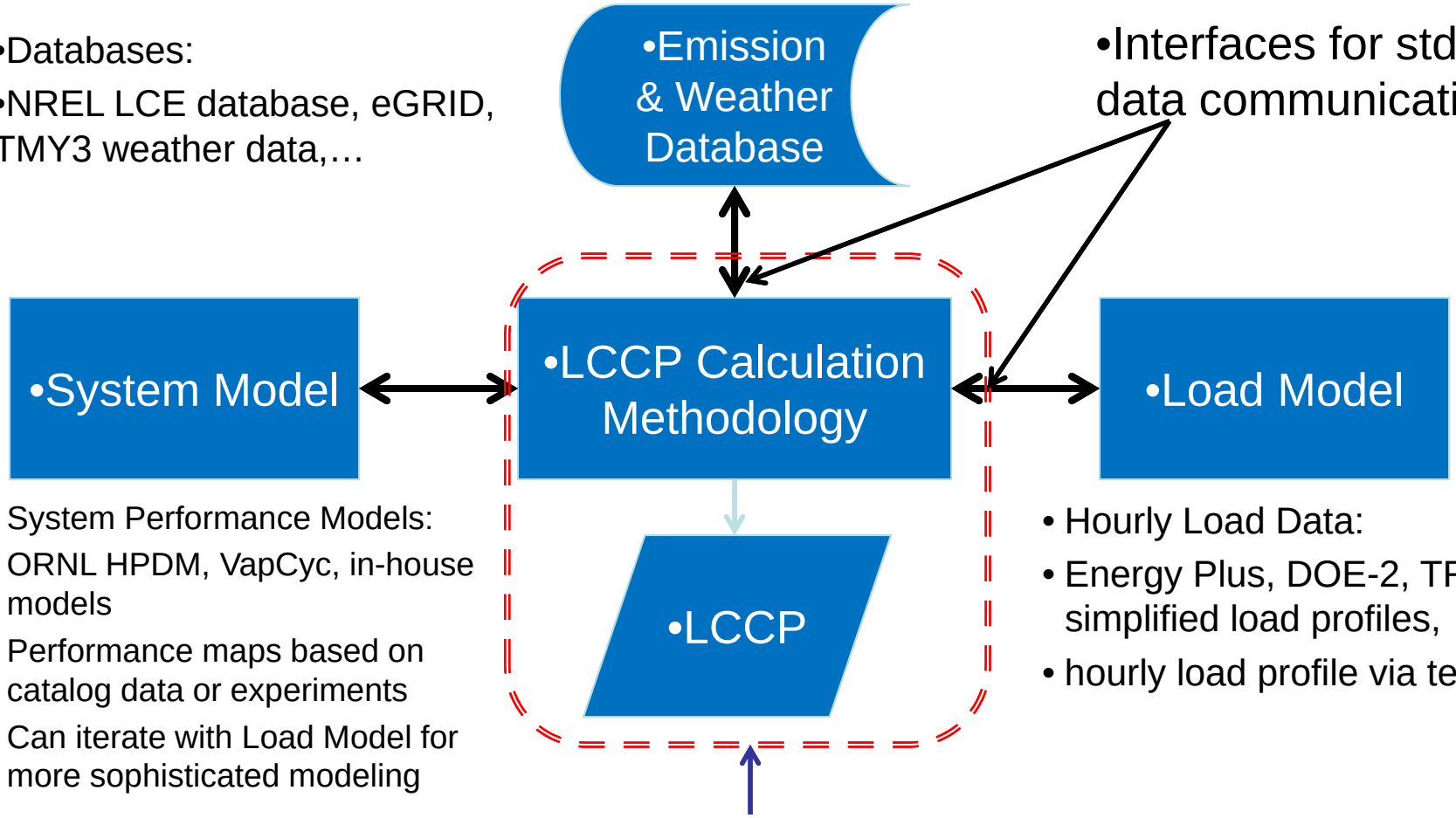
- **University of Maryland and ORNL team developed a web-based interactive LCCP modeling program for supermarket refrigeration based on user inputs (2012):**
  - **Users choose from 3 system types and 4 refrigerants**
  - **Utilizes 16 different locations in the US**
  - **13 systems inputs; 25 component inputs**
  - **Output includes total direct emissions and indirect emissions**



Tools Available

•Databases:

•NREL LCE database, eGRID, TMY3 weather data,…



- System Performance Models:
- ORNL HPDM, VapCyc, in-house models
- Performance maps based on catalog data or experiments
- Can iterate with Load Model for more sophisticated modeling

- Hourly Load Data:
- Energy Plus, DOE-2, TRNSYS, simplified load profiles,
- hourly load profile via text file

•Components will be developed as “Open Source”.

•Other components can be open-source or proprietary

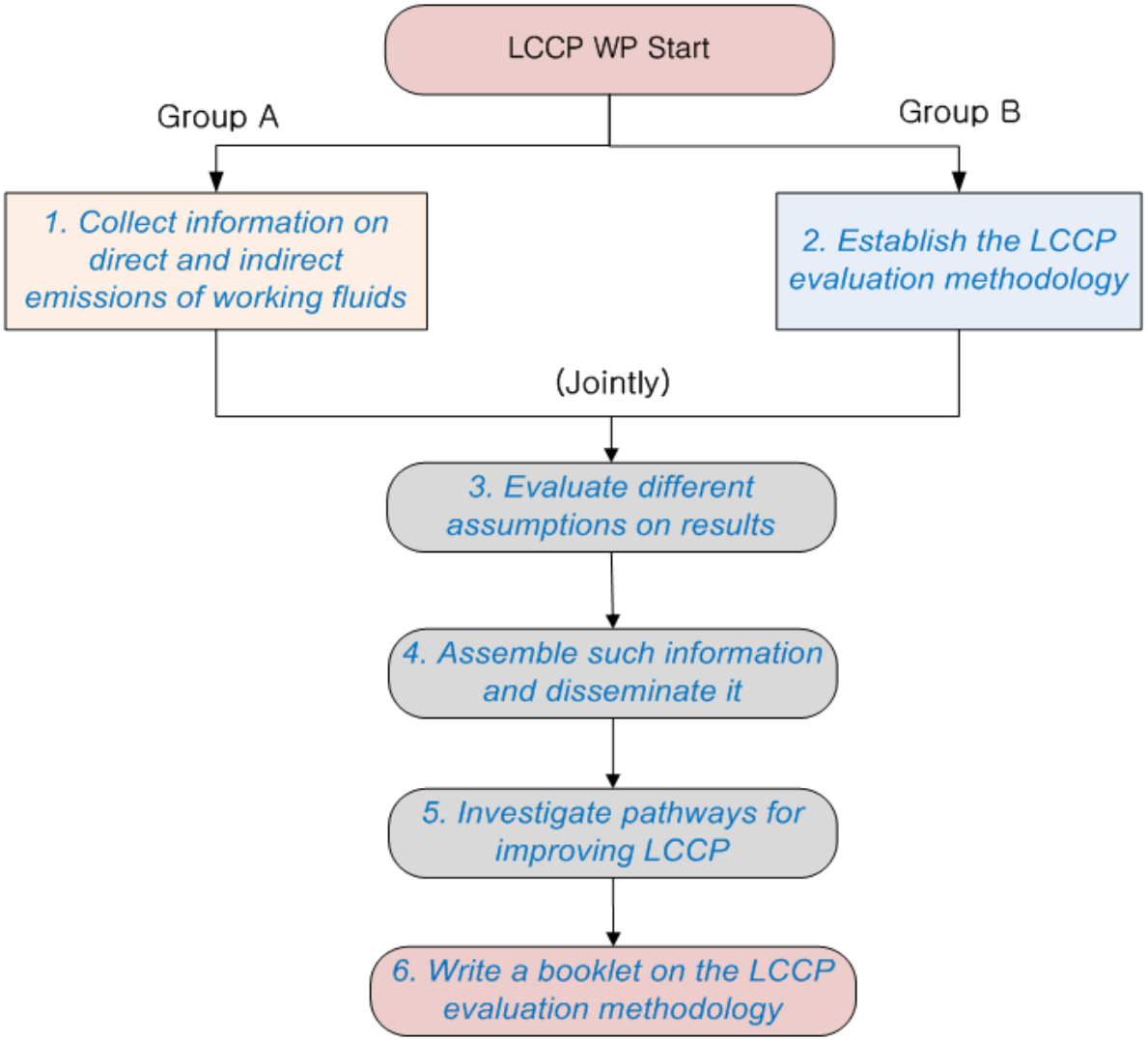
Basic Questions for LCCP

- **How to harmonize the LCCP methodology?**
- **How to improve accuracy?**
- **How to quantify the importance of each contribution (sensitivity)?**
- **Do we need different versions?**
  - **Research version for accuracy**
  - **Public version for easy use**

IIR's LCCP Working Party

- **In order to answer to previous questions, the IIR formed a working party to assess the merits of different methods for evaluating the environmental impact of refrigerants and to produce implementation protocols for these methods.**
- **Goal: Establish the harmonized LCCP evaluation methodology applicable for refrigeration and air conditioning systems**

IIR's LCCP WP Roadmap



IIR LCCP WP Reference Database

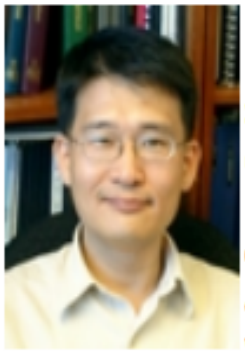
	A	B	C
1	Section No.	Details	Reference
2	3.1 Regular Emissions	Annual opearting	IPCC, 2006, Guidelines for National Gree
3			US: ADL, 2002, Global Comparative Anal
4			EU: D. Clodic, S. Barrault, 2011, 1990 to
5			Japan: JRAIA, 2004, LCCP of Some HVA
6			2006 IPCC Guidelines for National Green
7	3.2 Irregular Emissions		?
8	3.3 Service Emission	Installation	IPCC, 2006, Guidelines for National Gree
9		Repair service	?
10	3.4 End-of-Life Emission	Remaining	IPCC, 2006, Guidelines for National Gree
11		Recovery	IPCC, 2006, Guidelines for National Gree
12			EU: D. Clodic, S. Barrault, 2011, 1990 to
13	3.5 Leakage during Production & Transport		Johnson, C., 2004, Earth Technologies F
14	3.6 Decomposition		Weckert, W., 2008, D-NS, Thesis
15			
16			
17			
18			
19			
20			

1. System Information | 2. Geographic Information | **3. Direct Emission** | 4. Indirect Emisssion

IIR LCCP WP Website

- **A new web site of the working party is prepared.**

Working Party on LCCP Evaluation



Welcome to the Working party Web page

Since the main part of the global warming contribution from refrigeration equipment (including air conditioning) is due to indirect emissions, the climate performance of refrigerating system during its life cycle is an area of concern. Moreover, its proper evaluation is a key factor in determining the true impacts of working fluids for specific application and geographic location, and will assist in determining next generation working fluids for refrigeration and air-conditioning systems.

The IIR has therefore decided to set up a working party (WP) to assess the merits of different methods for evaluating the **Life Cycle Climate Performance (LCCP)** for refrigerating systems environmental impact of refrigerants and to produce implementation protocols for these methods, for use by decision makers and refrigeration stakeholders. **Yunho Hwang**, Vice-President of IIR Commission B1, is the chairman of this new WP, which started from January 2012, after approbation of the Science and Technology Council of the IIR.

LCCP WP: Membership

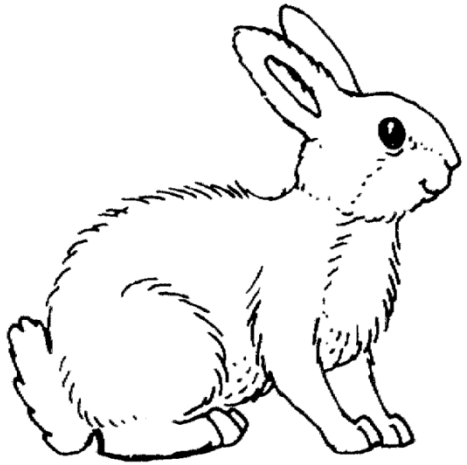
- The IIR is currently recruiting members from following areas for this WP:
  - Commission, private, and corporate members of the IIR
  - Experts whose knowledge of the subject will benefit the WP

You are invited!

Conclusions

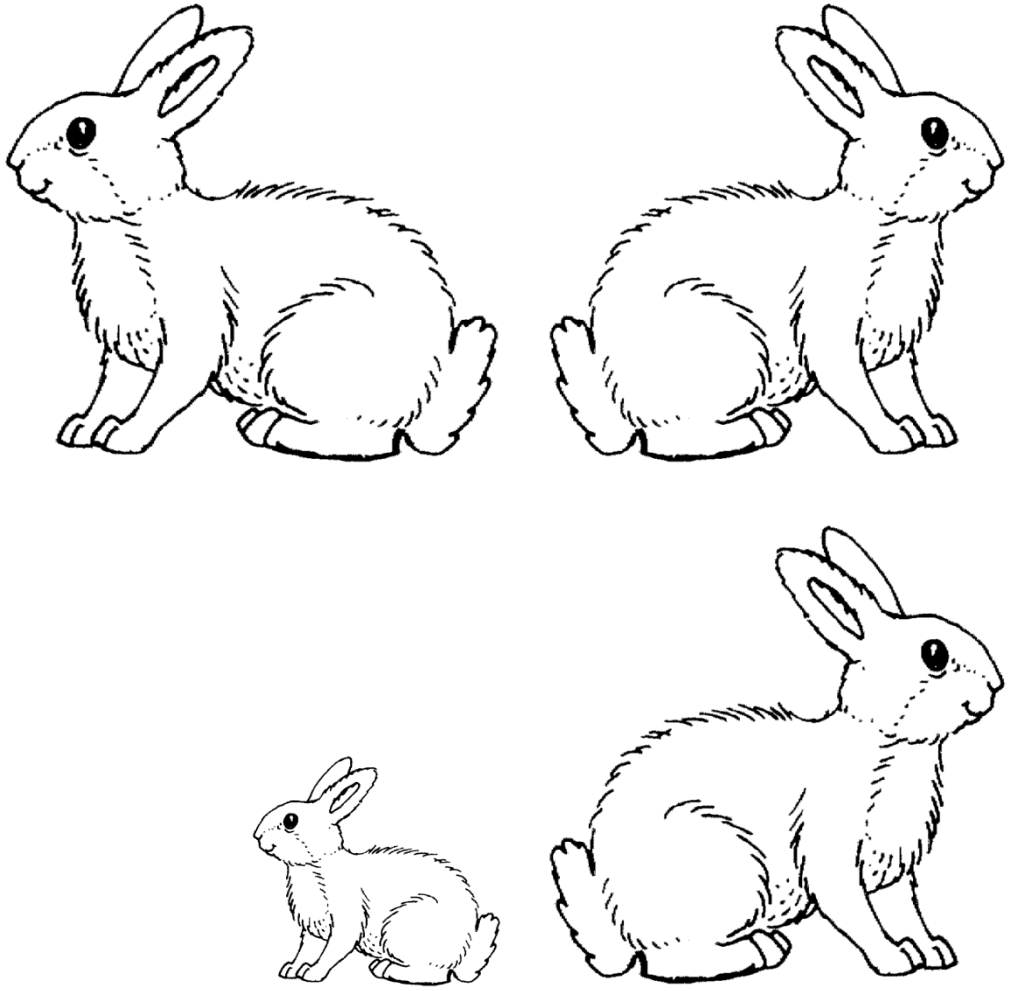
- **LCCP is an important tool in analyzing refrigeration systems and needs a globally harmonized approach**
- **Analysis must be region specific**
- **Increased R&D of more efficient components and systems will aid in use of more flammable and/or toxic refrigerants**
- **Additional safety measures will ensure low-GWP refrigerants deliver same level of performance in safe manner**

How can you catch a rabbit?



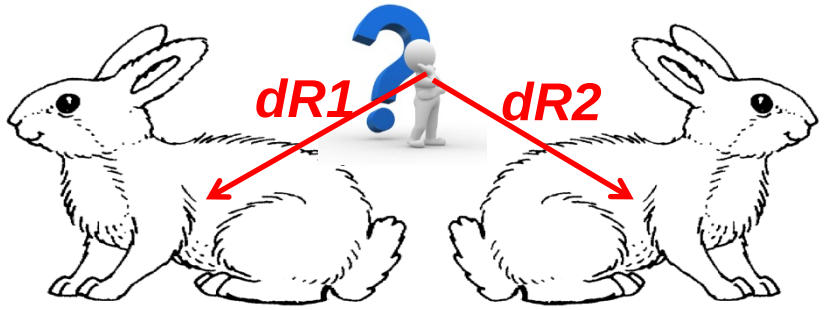
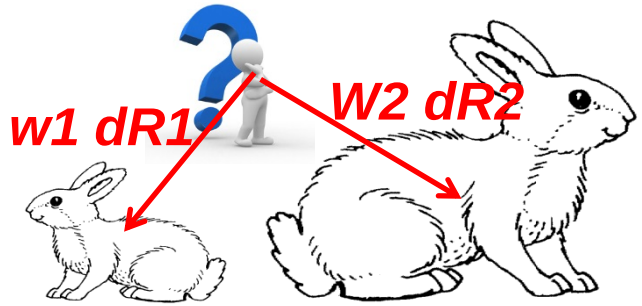
- **According to WikiHow.com:**
- **With a Simple Snare Loop**
- **With a Trapping Pit**
- **With a mall Mammal Trap**

What will happen if you try to catch two rabbits at the same time?

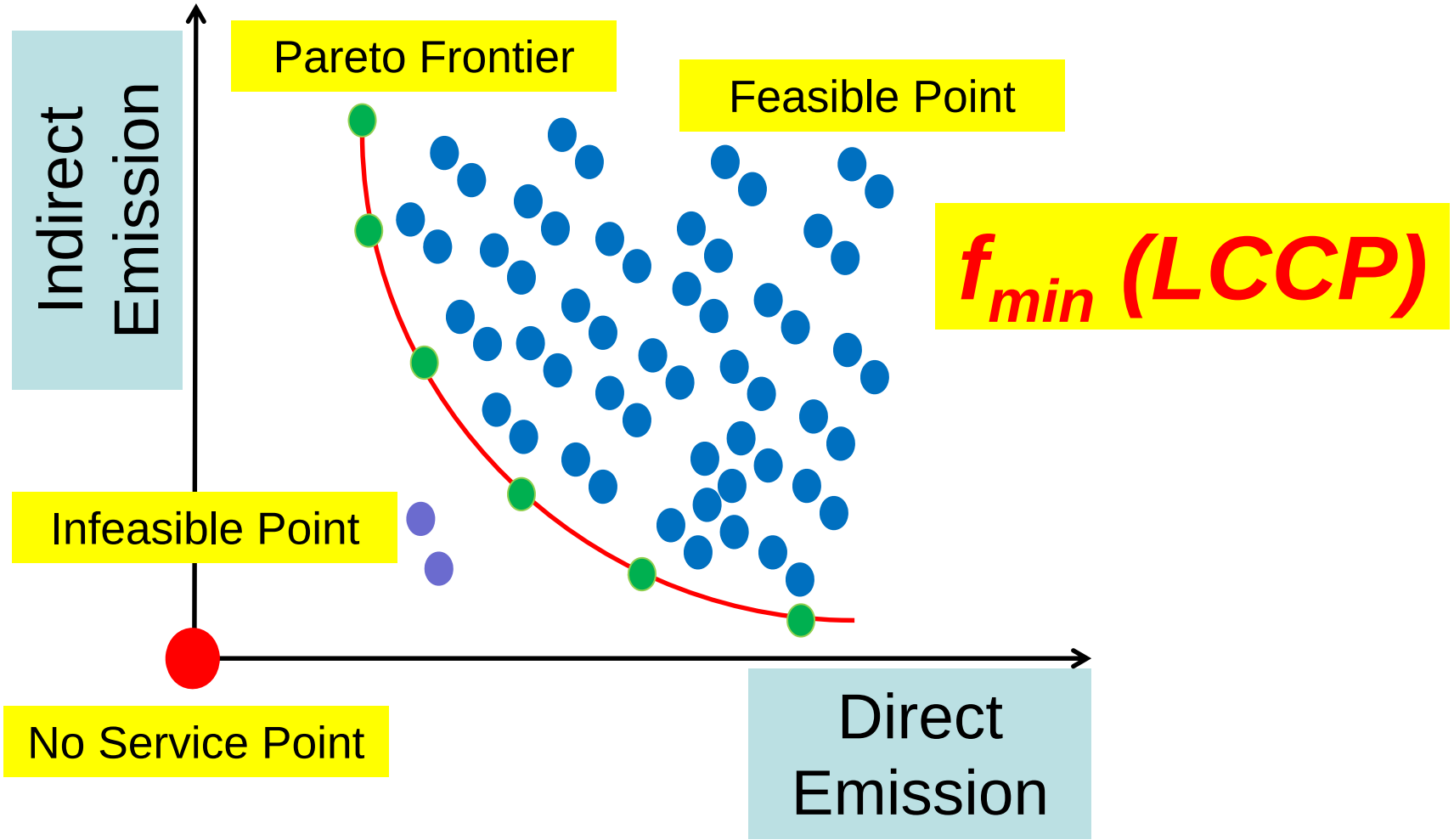


- Priority
- Right Target
- Focus

New Approach

	•**Single objective optimization:** ***min (distance R1)***
	•**Multi-objective optimization:** ***min (distanceR1, distance R2)***
	• **Static weighted aggregation** ***min ($w_1 dR_1 + w_2 dR_2$)*** • **Evolutionary dynamic weighted aggregation:** • ***changing the w1 gradually from 0 to 1 (or 1 to 0) during optimization.***

New Approach



Questions

- **IIR LCCP WP:**
  - http://www.iifiir.org/medias/medias.aspx?INSTANCE=EXPLOITATION&PORTAL_ID=portal_model_instance__WP_LCCP_Evaluation.xml
  - **GreenMAC LCCP:**
  - http://www.epa.gov/cppd/mac/
  - **AHRI LCCP Tool for Residential AC:** http://www.ahrinet.org/App_Content/ahri/files/RESEARCH/Technical%20Results/AHRTI-Rpt-09003-01.pdf
  - **UMD/ORNL LCCP Tool for Supermarket Refrigeration:**
  - http://lccp.umd.edu/ornllccp/