

## **GREEN-MAC-LCCP: Transparent, State-of-the-Art, Peer-Reviewed Analysis Tool**

**Dr. Stephen O. Andersen, U.S. EPA**

**Dr. Stella Papasavva, General Motors**

**Mr. Ward Atkinson, Chair SAE Interior Climate Control Committee**

Dr. Armin Hafner presented his personal views on the GREEN-MAC-LCCP model in the 1 April 2008 issue of R744.com, the well known website promoting CO<sub>2</sub>-based technologies. The GREEN-MAC-LCCP team welcomes input with new data and will continue to improve the model. However, we are confident that the GREEN-MAC-LCCP model is the best tool available today for evaluating lifecycle greenhouse gas emissions from mobile air conditioners. Dr. Hafner has not offered an alternative transparent and peer reviewed LCCP Model.

We are responding to correct errors in Dr. Hafner's description of GREEN-MAC-LCCP and explain how the model allows the best available life-cycle environmental performance comparison of competing air conditioning systems.

What is GREEN-MAC-LCCP model?

The GREEN-MAC-LCCP is a sophisticated accounting of the expected life-cycle climate impacts, expressed in terms of GHG emissions, of any vehicle air conditioning system. All data and assumptions are transparently presented in spreadsheet format so that any differences in climate performance between systems can be closely examined. Typical analysis will use standard input data and assumptions for the energy embodied in production of refrigerants and air conditioning system components, for climate and driving habits of specific locations, and for incremental energy consumption associated with AC operation. Data that is unique to a competing technology—such as GWP of refrigerants, refrigerant leak rates, AC system efficiency, and AC cooling capacity, is entered on the spreadsheet and automatically integrated into the analysis.

The GREEN-MAC-LCCP was developed and perfected by a global team of more than 50 world experts from the automotive industry, government, national labs, academia and other industry and non-governmental organizations. Advocates of every competing technology participate in the work.

Why was the GREEN-MAC-LCCP model developed?

It is self-evident that environmentally superior AC technology is defined by life-cycle impacts on climate, including the direct impacts of refrigerant emissions, the indirect impacts of fuel used to operate the vehicle air conditioning system, and the energy to manufacture, transport, and safely dispose the system, all expressed in terms of CO<sub>2</sub>-equivalent emissions. In years past, advocates of each competing new technology made 'black-box' claims of superiority but did not disclose data, assumptions, and calculation methods. The proposal for a global peer-reviewed analytical tool that assesses the GHG emissions of alternative refrigerants originated from U.S. EPA's, Dr. Stephen Andersen.

Dr. Andersen's idea was endorsed in roundtable discussions at several workshops where experts identified General Motors and JAMA as having the best proprietary life cycle software. Ward Atkinson and Stephen O. Andersen persuaded General Motors to support the project in 2004 and in January 2005 Stella Papasavva and Stephen O. Andersen persuaded JAMA member companies to contribute their expertise and intellectual property.

Early in 2005, SAE International established a Working Group with GM's Dr. Stella Papasavva and Mr. William Hill chairing the global LCCP team with the goal of developing and disseminating the model for public use.

How is GREEN-MAC-LCCP Used?

The LCCP model is hosted on the website of the EPA Climate Protection Partnership Division, which sponsors the Mobile Air Conditioning Climate Protection Partnership. It is near perfection and will soon be submitted for ballot for a SAE International J Standard. Once published, it likely will be the global standard for measuring climate performance for vehicle AC regulations and possibly for quantifying GHG emissions in carbon trading.

The GREEN-MAC-LCCP is globally peer reviewed and is now accepted by vehicle OEMs, HVAC suppliers, governmental organizations, and other industry associations, as the most credible method for a fair environmental cradle-to-grave performance comparison of any automotive refrigerant systems.

Dr. Hafner's R744 Interview

Dr. Hafner is a member of the GREEN-MAC-LCCP global team, a R744 member, and a staff member at SINTEF. Because he has voiced support for the model in the team meetings, his criticism in the R744.com interview is somewhat surprising, particularly because his questions had been discussed and resolved in the SAE Working Group during the various LCCP meetings. Dr. Hafner has not offered an alternative transparent and peer reviewed LCCP Model.

Dr. Hafner's statement:

*"In its current state, the model does not open for fuel over consumption input data from real-life testing, collected by carmakers and suppliers. The calculation is solely based on bench tests carried out in one laboratory in the U.S. to ensure consistency"*

Response:

Contrary to Dr. Hafner's statement the model allows the user to enter data obtained by any laboratory bench-test experimental set-up. A global OEM effort, led by Mr. Hill, came to OEM consensus that bench-test results are the most reliable source for AC system energy consumption. SAE CRP data are now

publicly available, and are a fair basis for comparing proposed alternative refrigerants.

The model automatically reports GHG emission totals that can easily be converted to fuel consumption for the indirect emissions associated with AC operation during driving.

Dr. Papasavva has reported good agreement between GHG emissions estimated by GREEN-MAC-LCCP from laboratory bench-scale tests, driving simulations used to satisfy fuel efficiency regulations, and different drive-cycle vehicle tests.

Frequent global LCCP meetings are held to further perfect the model and to incorporate vehicle-based test results in future versions of the model. The GREEN-MAC-LCCP team recognizes the need for a common approach to fuel consumption measurement of AC systems and has been discussing this for some months but as pointed out in the public studies done by the EU [ref. TNO report 05.OR.VM.014.1/RJV] this is a challenging effort. Once this activity is matured the LCCP team may benefit from that effort.

Dr. Hafner's statement:

*"Here the model is too optimistic, as it bases its calculations on a best-case scenario for direct R134a emissions. Unfortunately, the assumed 90% rate of proper recycling without any leakages for India does not correspond to reality where the actual leakage of R134a at servicing and disposal might be much higher than shown in the model."*

Response:

The global team has data published by the Mobile Air Conditioner Society Worldwide, the U.S. EPA's Vintaging model, data from JAMA including industry and official governmental sources, data from VDA and data from other European OEMs (including B-Cool and Fiat).

The most recent updates to the model also incorporates new direct leak rates by considering not only best refrigerant recycling practices (90% refrigerant recovery) but also attributing a higher end-of-life direct refrigerant emissions when a complete refrigerant charge release takes place. The model actually weighs more heavily (60%) the complete charge release than the 90% refrigerant recovery at service (40%). Furthermore the model estimates direct refrigerant leaks during servicing from professional people and from DIY procedures with much higher emissions than professional service.

Each city is treated differently with respect to both Operating and Service direct leaks using best available data. The LCCP model comprehends the 20% leaks from the banks (old vehicles) but the frequency of service is estimated using a

more complex methodology than Dr. Hafner's two-time per lifetime suggestion. The model takes into account the work by Dr. Denis Clodic funded by the EU and recognized as the state-of-the-art leak rate assessment by the industry and governments around the world. As more data become available the model will update the leakage input spreadsheets.

New data and model improvement:

In March 2008, SAE sent a letter to the United Nations Environment Programme Division of Technology, Industry and Economics (UNEP DTIE) and national environmental authorities requesting regional information on how mobile air conditioning systems are used and serviced. This data will further improve the GREEN-MAC-LCCP results.

The GREEN-MAC-LCCP team welcomes new data and will continue to improve the model. However, based on the extensive process that has been conducted to obtain the best possible framework and data for this model, we are confident that the GREEN-MAC-LCCP model is the best available tool for evaluating lifecycle greenhouse gas emissions from mobile air conditioners. Mindful of the complexity, we welcome consensus efforts to develop reliable and objective road testing procedures for MAC environmental performance.