

A regulatory strategy for

Including MAC fuel consumption in vehicle fuel efficiency standards

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TNO Automotive



Desired results of legislation on MAC's CO₂ emissions and fuel consumption

- **Create public awareness and influence behaviour concerning the effect of MAC on fuel consumption and CO₂ emissions (*labelling*)**
- **Stimulate construction and sales of efficient MAC systems and vehicles (*ranking*)**
- **Establish Emission factors for inventories**

Factors of influence

- **To be influenced :**
 - **Cooling technology**
 - **Vehicle body design**
 - **Human behaviour**
- **Fixed :**
 - **Environmental conditions**

Ways to influence the environmental effects of vehicle cooling

- **Create separate MAC's type approval legislation and a test procedure**
- **Voluntary agreement with manufacturers on minimal performance level of MAC's**
- **Include MAC's operation in current type approval procedure for a complete vehicle**
- **Initiate Euro NCAP like approach**
- **Start information campaigns (based on measured data)**

Work already done :

- US work (other?)
 - focussed on regulated emissions (not CO₂)
 - Maximum load test
 - Including radiation

Therefore :

- CO₂ not yet addressed
- No stimulation of intelligent systems

Therefore a different approach is necessary^P EC project

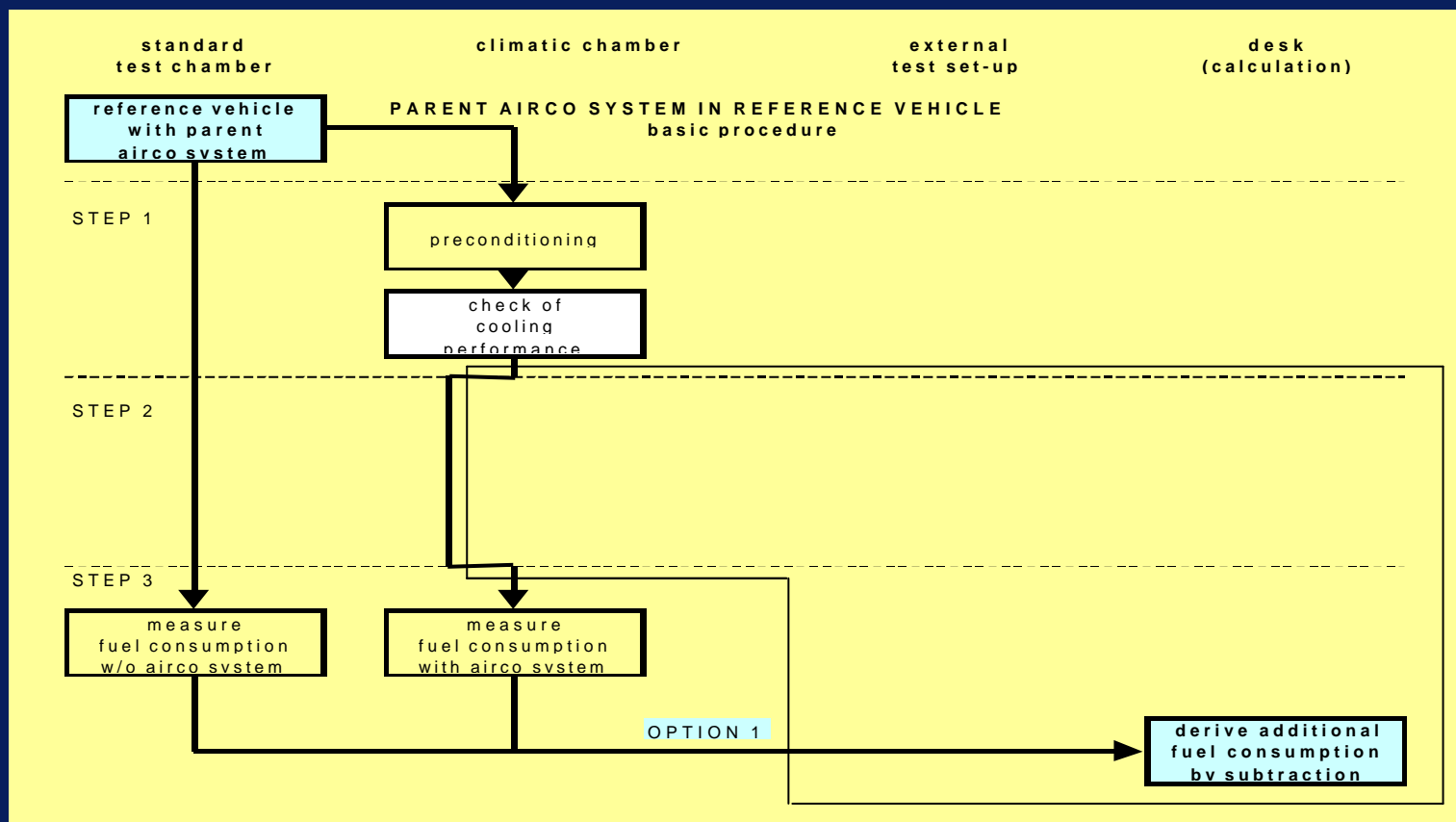
EC Project goals :

- **Insight into the extent of the additional emissions caused by the use of air conditioners and aux-heaters in EU**
- **Evaluate possible options to include airco/heaters into the CO₂-type-approval test**
- **Give information on the cost effectiveness of such a procedure**
- **Give a concrete proposal for amending directive 80/1268/EEC (Fuel consumption) and possibly Directive 70/220/EEC (emissions)**
- **All resulting in a *cost effective* way to:**
 - **categorize the GHG effects of MAC systems (ranking)**
 - **produce figures for labeling purposes (labeling)**
 - **If possible establish emission factors**

Key points in the Type Approval implementation approach :

Simplicity of procedure \hat{U} cost effectiveness

simplest = each type 1 additional test (with MAC) = *expensive*



Solution

family and subsystems approach

- Division of vehicle into 3 subsystems
- Determination of performance parameters per subsystem
- Calculation of MAC's additional CO₂ emissions / FC per family, preferably using default factors were possible

The 3 subsystems

Subsystem 1:

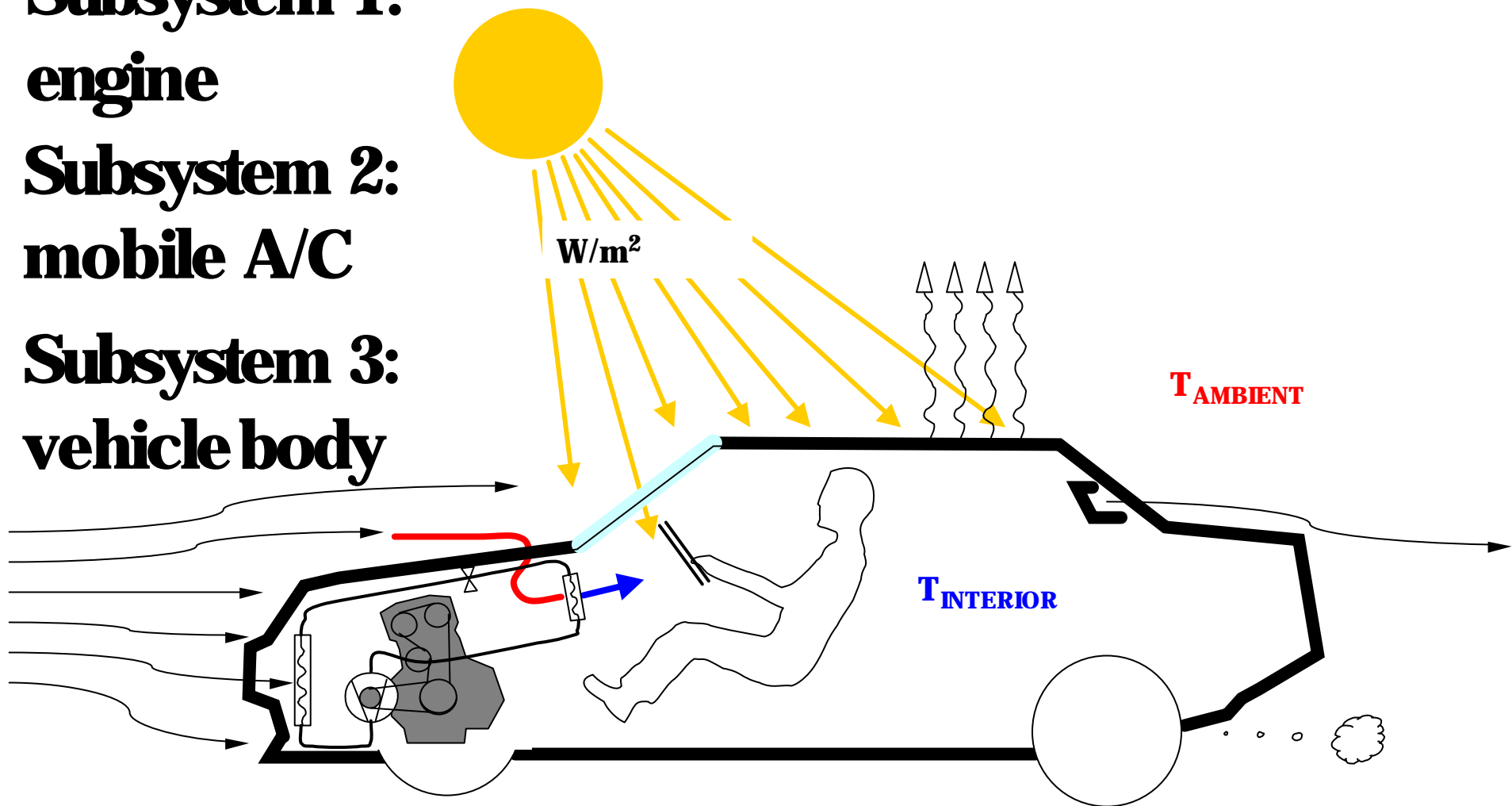
engine

Subsystem 2:

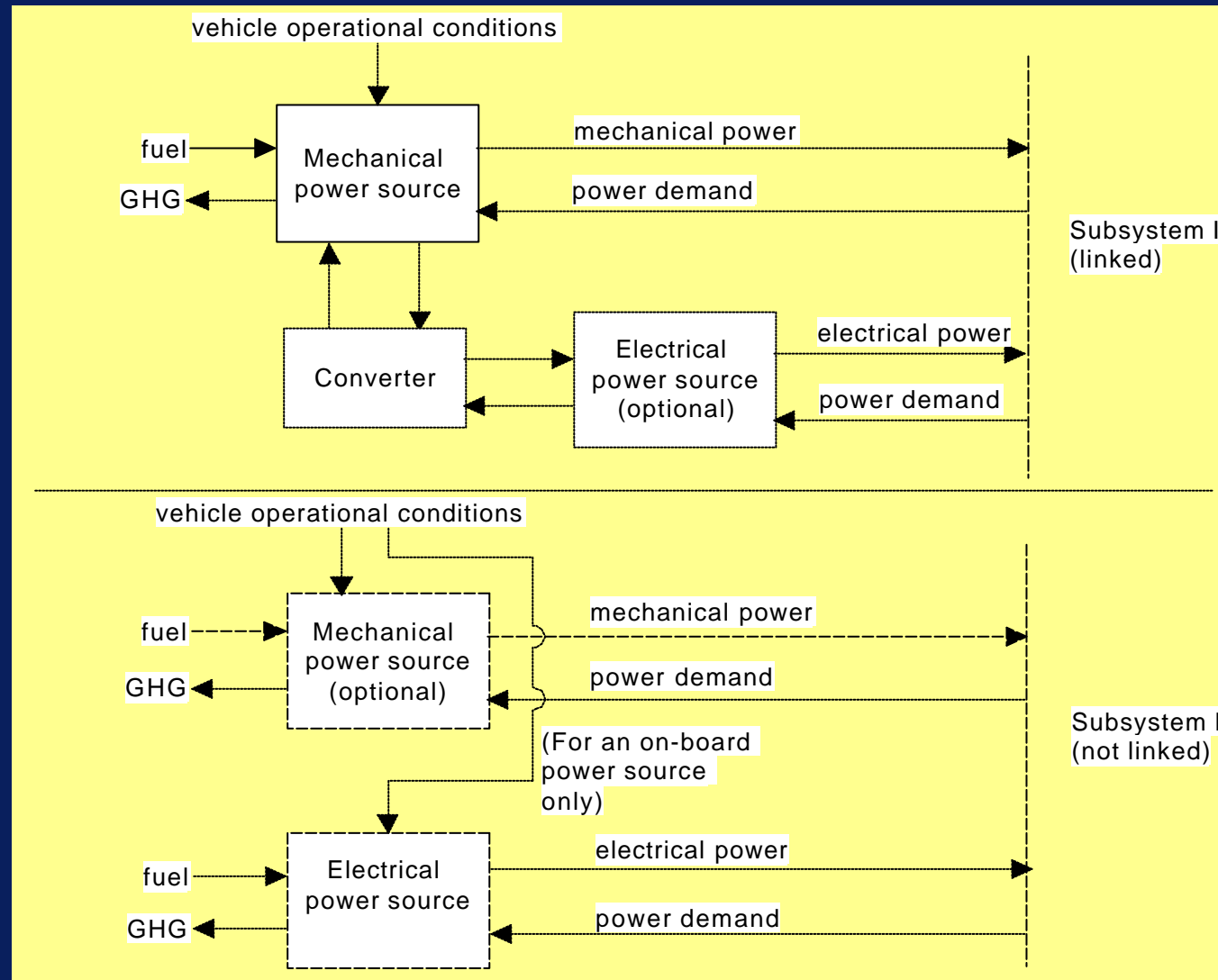
mobile A/C

Subsystem 3:

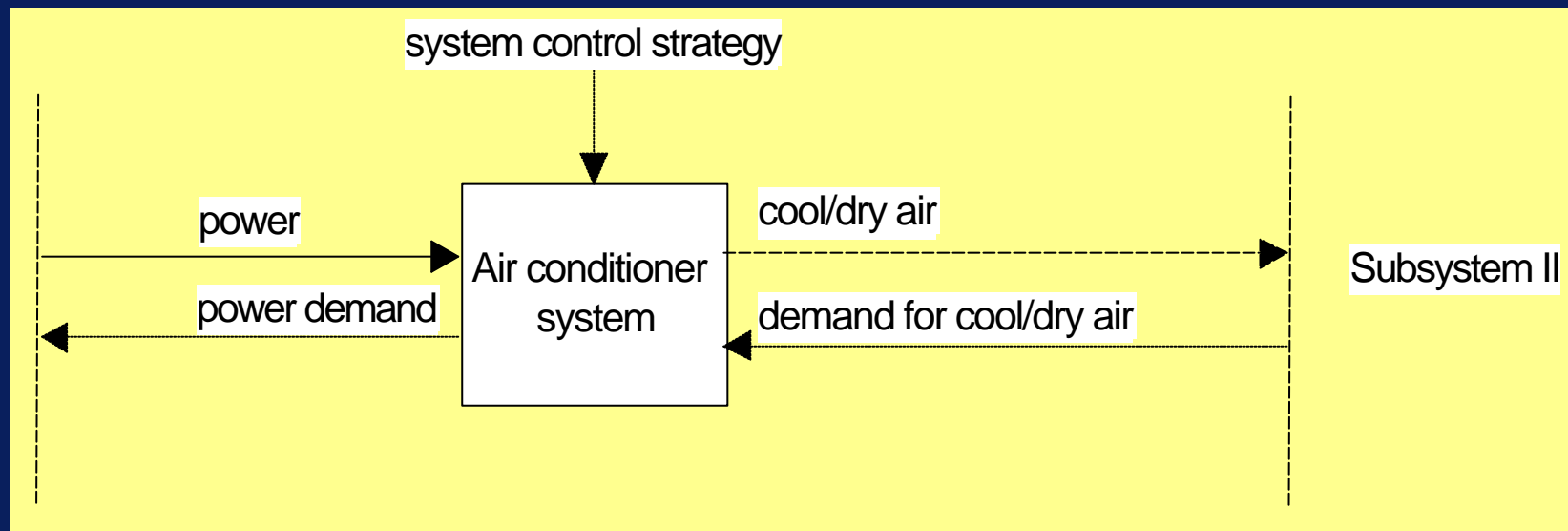
vehicle body



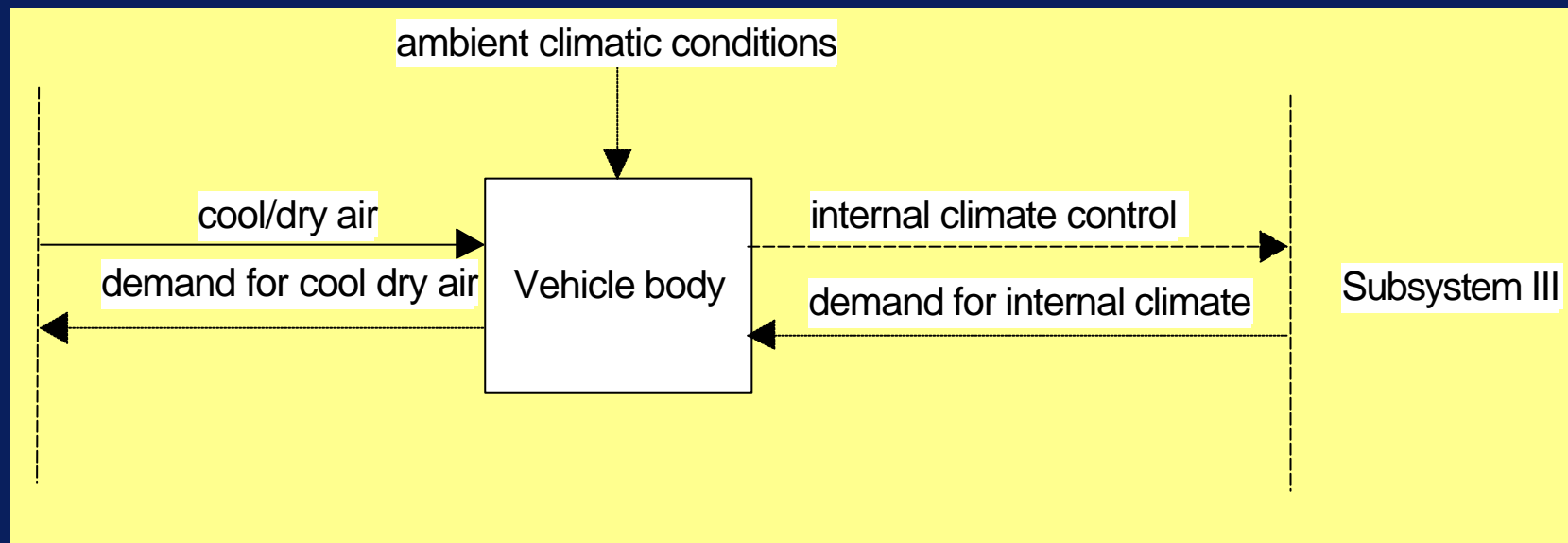
Subsystem 1 (engine)



Subsystem 2 (MAC)



Subsystem 3 (vehicle body)



Tentative proposal for a legal procedure

3 step family approach

- 1. Measure cool air need of a parent body**
- 2. Measure drive power of the installed MAC**
- 3. Calculate additional CO₂ emission / fuel consumption**

Step 1

Step concerns	Type of action	Input	Output
<i>STEP 1</i> Determination A/C performance needed	Measurement on parent Check on family members	Temperature profile	Required CFF [K*kg]

Step 2

Step concerns	Type of action	Input	Output
STEP 1 Determination A/C performance needed	Measurement on parent Check on family members	Temperature profile	Required CFF [K*kg]
STEP 2 a) Determination of A/C drive energy b) Determination of compressor speeds	Measurement on 'worst case' system	CFF of parent Standard test cycle	Drive energy over cycle X [kWh] mech. Y [kWh] electr.

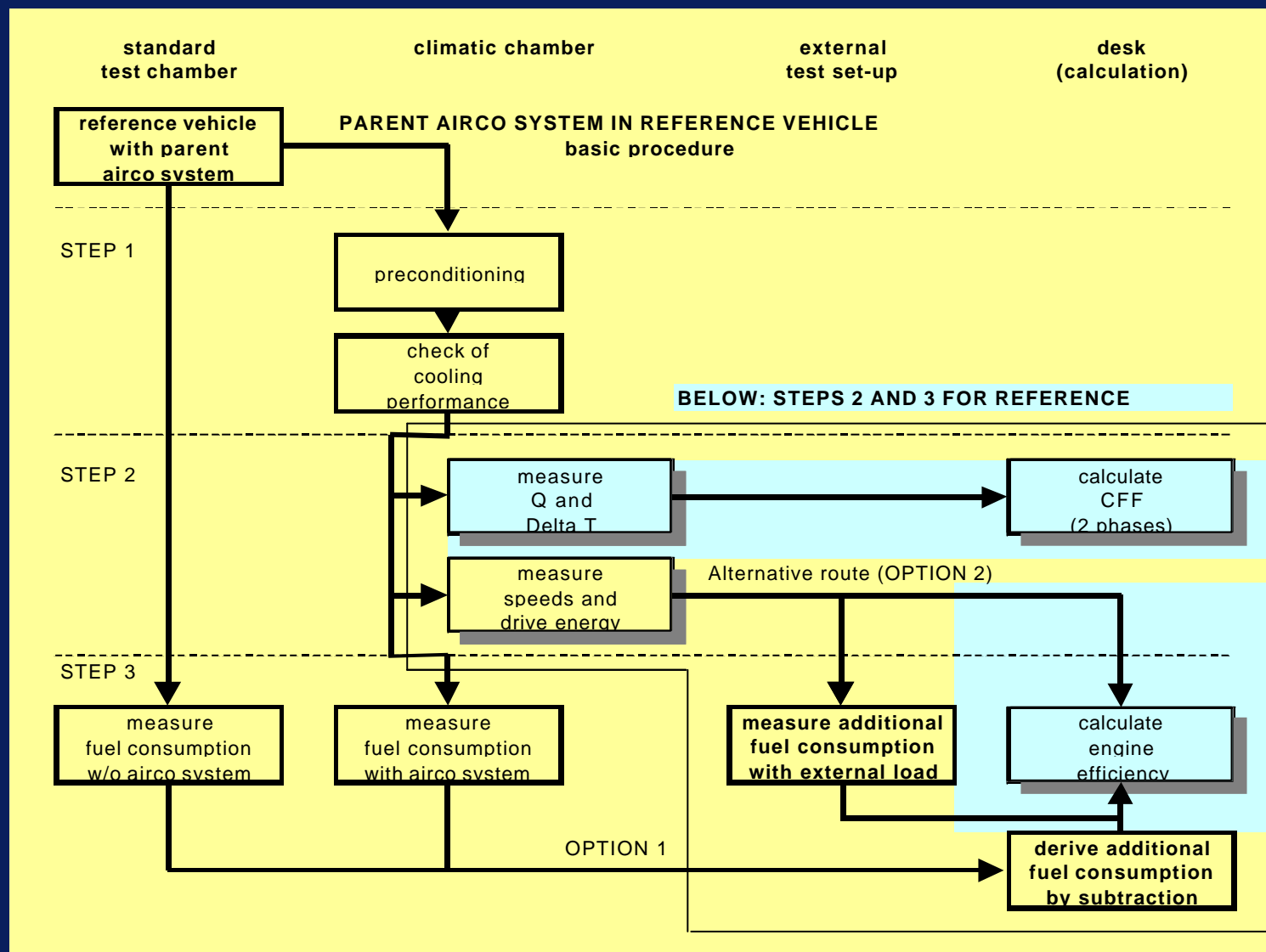
Step 3

Step concerns	Type of action	Input	Output
STEP 1 Determination A/C performance needed	Measurement on parent Check on family members	Temperature profile	Required CFF [K*kg]
STEP 2 Determination of: a) A/C drive energy b) compressor speeds	Measurement on 'worst case' system	CFF of parent Standard test cycle	Drive energy over cycle X [kWh] mech. Y [kWh] electr.
STEP 3 Determination of: a) Additional FC and CO2 b) Engine efficiency factor of parent (for use with family members)	Measurement/calculation	Output of: STEP 2 of family member or STEP 3b of parent	FC [litre/test] and CO2 [g/test] Reference engine efficiency factor

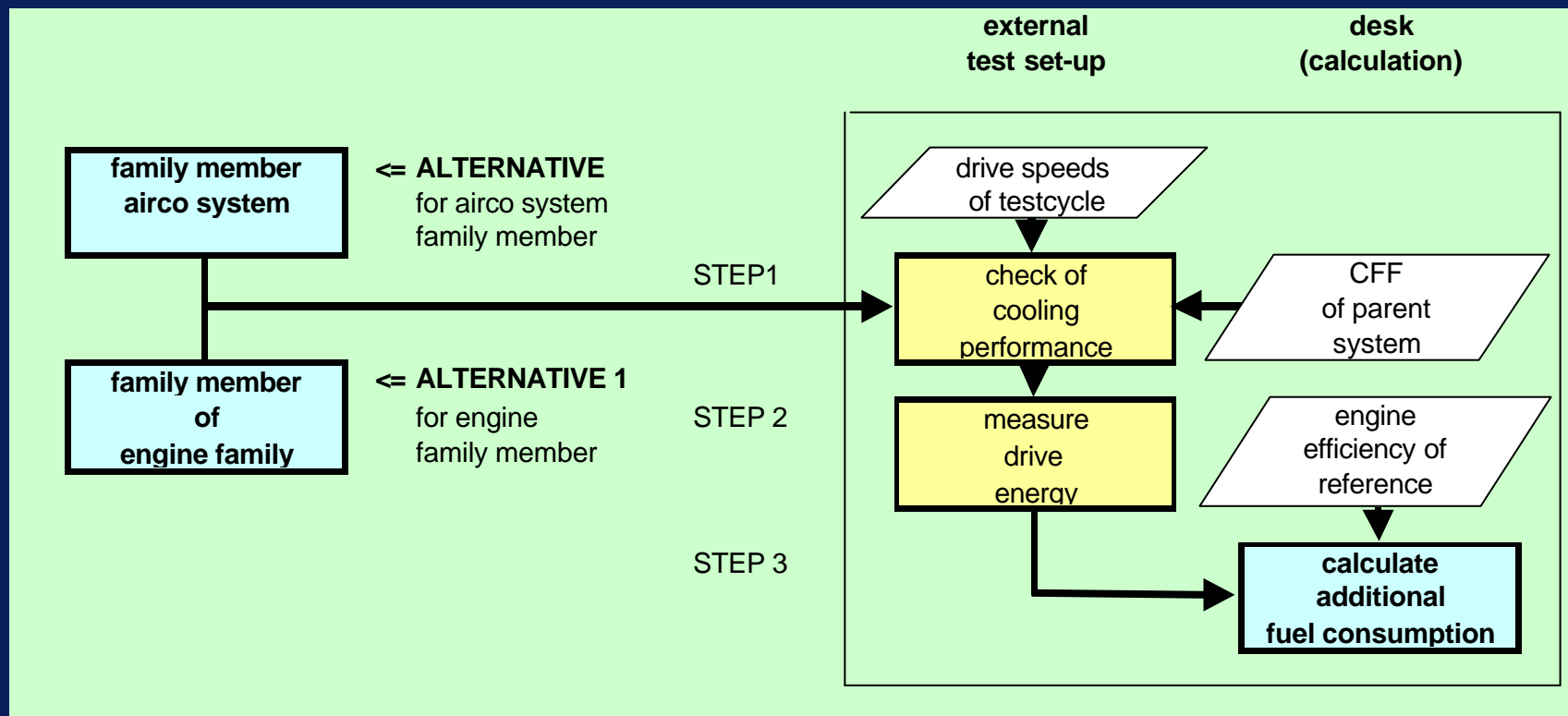
Presentation

Step concerns	Type of action	Input	Output
STEP 1 Determination A/C performance needed	Measurement on parent Check on family members	Temperature profile	Required CFF [K*kg]
STEP 2 a) Determination of A/C drive energy b) Determination of compressor speeds	Measurement on 'worst case' system	CFF of parent Standard test cycle	Drive energy over cycle X [kWh] mech. Y [kWh] electr.
STEP 3 Determination of: a) additional FC and CO ₂ b) engine efficiency factor of parent (for use with family members)	Measurement/calculation	Output of STEP 2 of family member, or STEP 3b of parent	FC [litre/test] and CO ₂ [g/test] Reference engine efficiency factor
PRESENTATION <i>Effect on FC and CO₂ of air conditioner per test</i>	Calculation	Output of STEP 3	LABEL FC(CO ₂) [litre(gr)/100 km] [litre(gr)/hour] [litre/year]

Reference data for family members



Simplified procedure for airco (or engine) family member

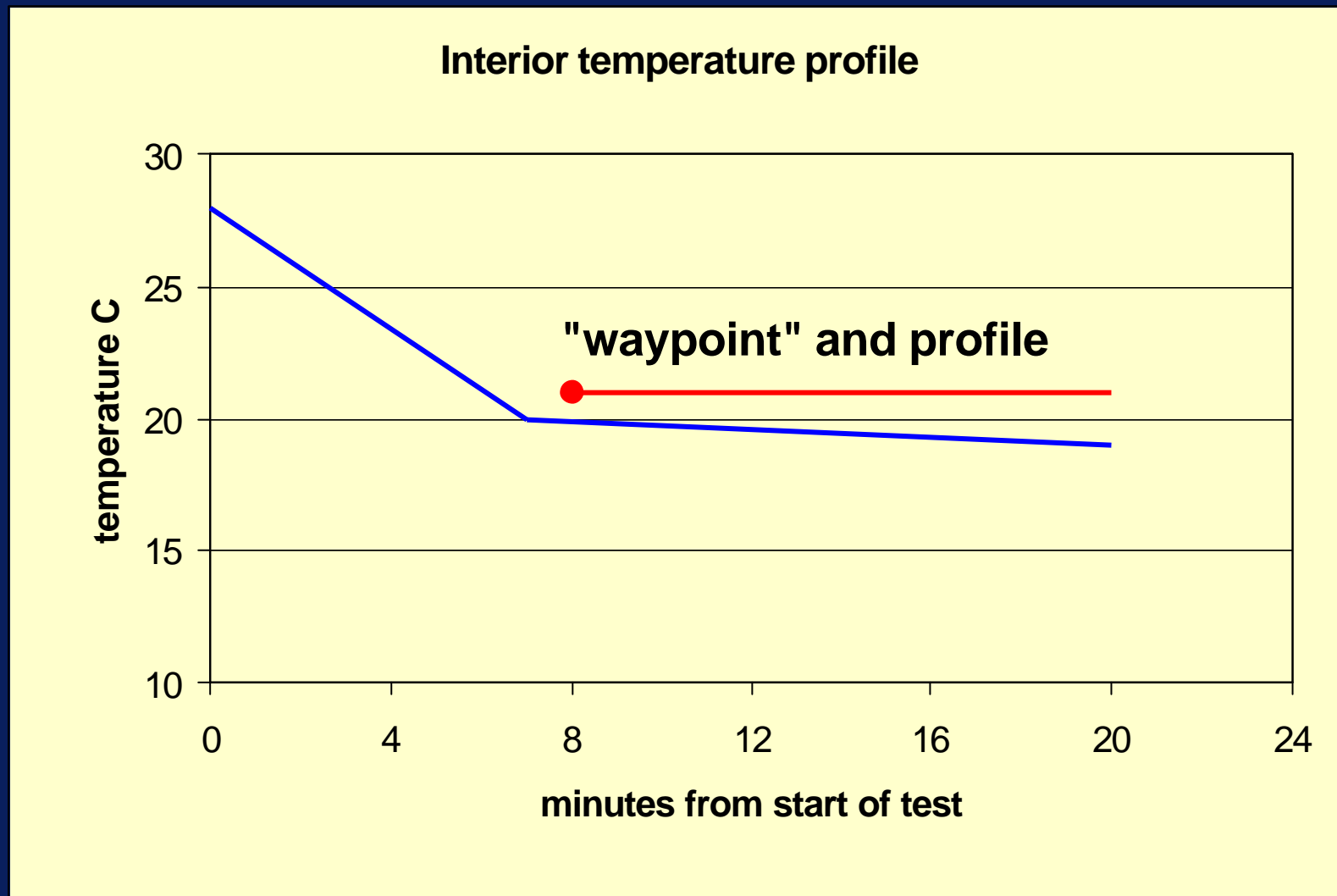


Technical set-up of the test procedure

- Replication of the TA test with MAC on at 1 parent vehicle
- Cooling performance defined while passing a “way point”
- Using the NEDC driving cycle
- Executed in a climatic chamber under *one* set of standard test conditions, including radiation
- Measuring a complete data set on the parent vehicle

- Calculating the effects for defined vehicle families

The “way point” in the cooling profile



Proposed test conditions

Condition	Unit	Value	Comments
Ambient temperature	°C	26	This value should be adjusted to the temperature that is best represented in the annual (daytime) temperature distribution.
Required inner temperature	°C	21	Standardised location
Ambient humidity	%	60	at 26°C (ca.13 g/kg dry air)
Ambient radiation intensity set point	W/m ²	850	To be reviewed from the climate data
Vehicle driving cycle	--	Current emission test	To be reviewed in general context
Frequency of use:			
Zone 1	%	6	Northern EU
Zone 2	%	11	Central EU
Zone 3	%	33	Southern EU

Test costs

Costs per manufacturer, based on 10 body and 10 engine variants [kEuro]				
test scenario		Nr. of dif. MAC systems per family		
		1	2	5
a	double test for each body-engine combination	360	720	1800
b	subsystem approach body and engine measured	102	109	129
c	subsystem approach body measured. Engine simulated	87	93	114
costs per car sold [Euro]		scenario	a	c
Small car brand (2 bodies, 10.000 per type)			14	2
large car brand (10 bodies 1.000.000 per type)			0.72	0.09

Conclusions

- A ranking and labelling method for CO₂ emissions of MAC's in passenger car's can be set up
- The integration of such a set-up into TA is feasible
- The cost (efficiency) of the procedure largely depends on the amount of default values that can be used
- Emission factors establishment in only cost effective through a separate project

Work still to be executed :

- **Validation of the procedure selected, on :**
 - practicality of the proposed procedure
 - default factors
 - Detailed input for cost effectiveness calculation
 - optimal family definition
- **Emission factors establishment (separate issue)**