

Status of ETSAP TIMES – Maintainer Report

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New Features in ETSAP TIMES Versions 4.0–4.9

Major New Features

New Feature	Version	Extension	
Dispatching and unit commitment features	4.0	- / DUC	
TIMES-Micro – Elastic demand functions (with substitutions)	4.1	MICRO	
Retrofitting and life extensions of technologies	4.1	-	
Support for grid computing and MCA with sensitivity analysis	4.2	MCA	
Support for demand load shifting processes	4.3	-	
Ancillary Balancing Services (capacity reserve markets)	4.4	ABS	
TIMES-Macro – Linearized Formulation (experimental)	4.5	MLF	
Logit market sharing mechanism (experimental)	4.7	ECB	New
Enhanced grid modelling features (PTDFs, Weymouth eqs.)	4.8	-	New
User-defined agents supported in Climate Module (tentative)	4.9	CLI	New

Minor new features – 1

New Feature	Version	Related attribute
Shaping of capacity transfer coefficients	4.0	<u>NCAP_CPX</u>
Functional depreciation rates for salvage value	4.0	<u>NCAP_FDR</u>
Defining fixed input flow profile for storage via COM_FR	4.1	COM_FR
Reporting of market share constraint marginals	4.2	PRC_MARK
New attribute for uncertain taxes/subsidies	4.2	<u>S_FLO_TAX</u>
Reporting of power levels of flows	4.3	RPT_OPT
Variable timeslice cycles and dynamic timeslice tree	4.3–4.4	<u>TS_CYCLE</u>
Automatic filtering off domain violations in input data	4.3	DATAGDX
Option for reporting selected flows on ANNUAL level	4.4	RPT_OPT
Defining maximum lifetime cycles for storage	4.4	<u>STG_MAXCYC</u>

(New input attributes underlined)

Minor new features – 2

New Feature	Version	Related attribute
Filtering off small values in reporting parameters	4.4	RPT_OPT
Support for fixing capacities to previous solution	4.4	<u>REG_BDNCAP</u>
Enhanced formulation for general storage (STS)	4.5	STSFLX
Support for independent input/output AFs for storage	4.5	NCAP_AFC
Non-vintaged FLO_FUNC and ACT_FLO for vintaged prc	4.5–4.7	FLO_FUNC
Parameter for proportional investment subsidies	4.5	<u>NCAP_ISPCT</u>
Dynamic bound constraints for COMPRD / COMNET	4.5	UC_DYNBD
Shaping of capacity-related flows by age	4.6	FLO_FUNCX
Support for risk-free reference rate for hurdle rates	4.6	<u>G_RFRIR</u>
Shaping of seasonal availability factors	4.6	<u>NCAP_AFSX</u>

Minor new features – 3 (new)

New Feature	Version	Related attribute
Support for using NCAP_ICOM for past investments	4.7	NCAP_ICOM
Option for outputting process units in GDX file (via PUNITS)	4.7	<u>PRC_UNITS</u>
Support for shaping NCAP_OCOM based on COEF_CPT	4.7	FLO_FUNCX
New IE option -13 for flushing out time series (bounds etc.)	4.8	BND / RHS
Reporting option for including past investments in Cap_New	4.8	RPT_OPT
Option for reformulating FLO_FR equations for performance	4.8	FLO_FR
Added dump-out option of IE processed input data GDX	4.8	DATAGDXI
Support for adjusting CHP reduction heat gain (if modelled)	4.9	PRC_ACTFLO
Reporting option for capacity retirements (Par_CapRet)	4.9	RPT_OPT
New attribute for defining flow bounds as power rate levels	4.9	<u>FLO_BDLVL</u>

Major New Features

Logit Market Sharing Formulation – experimental

- Simulation of imperfect markets can be modeled via a market sharing algorithm giving a non-zero market share to technologies that are not optimal but are to some extent judged competitive, or close enough to optimality, to deserve a market share
- The closeness to competitiveness may be determined using a levelized cost measure or the dual information for each technology, together with adjustments incorporating intangible costs and preferences
- The TIMES Logit Market Sharing formulation provides such a market sharing mechanism
 - Always based on the levelized cost (LEC) measure, calculated by TIMES
 - The heterogeneity parameter defines the sensitivity of the market share on the LEC
 - User may define optional preference weights and intangible costs as socioeconomic factors
 - User may also define a penalty cost for relaxing each market share constraint (such that there is an upper limit for the distance from optimality to be able to gain market)
- The algorithm requires re-solving the model after determining the adjusted market shares
- Implemented as a TIMES extension ECB (for Economic Choice Behavior)
 - Requires activation by: \$SET ECB YES
 - Currently an experimental feature of TIMES
- For more details, see:
https://github.com/etsap-TIMES/TIMES_Documentation/blob/master/User_Notes/TIMES-Logit-Market-Sharing.pdf

Enhanced Grid Modelling Features:

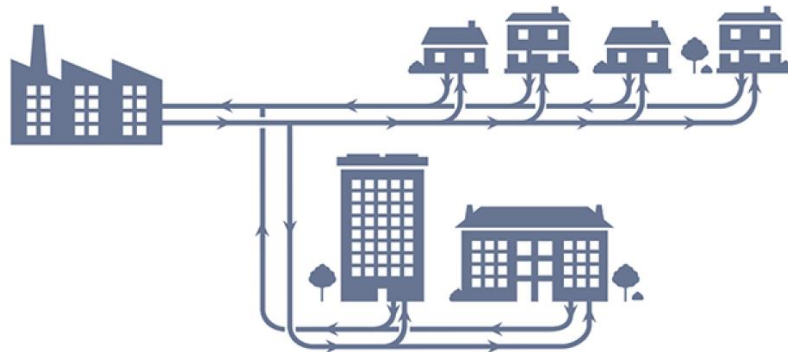
Extending the features for various kinds of grids



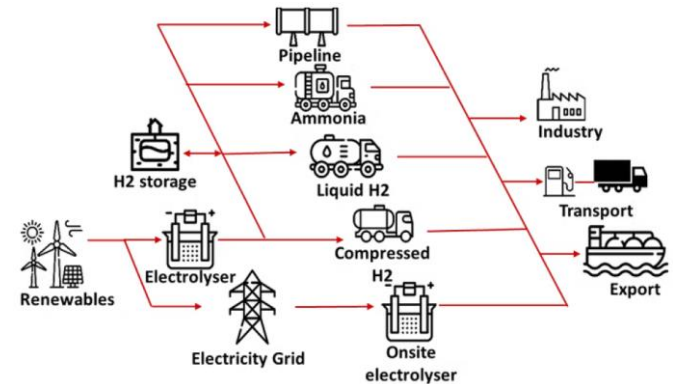
Electricity grids



Gas and CO₂ grids



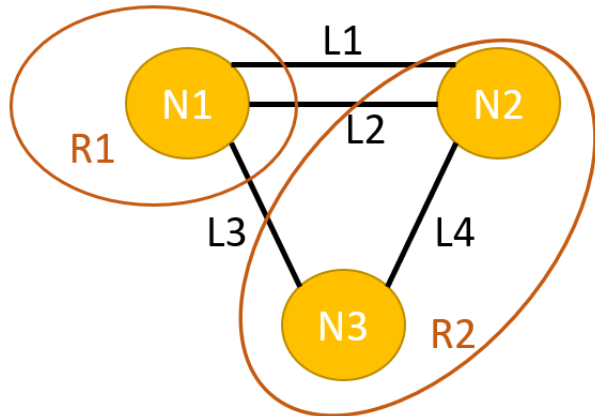
District heating grids



Hydrogen grids

Enhanced Grid Modelling Features – 2

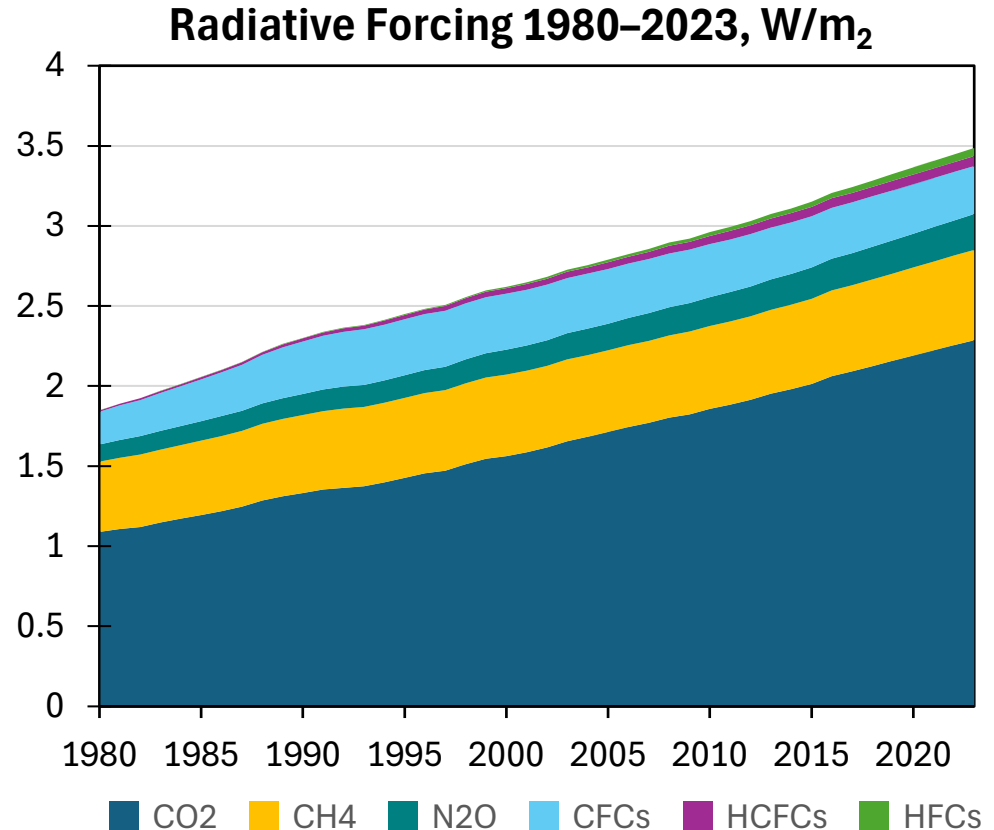
- New PTDF Formulation for grid power flows (or even other types of grids)
 - Supports also transmission expansion planning (with MIP or RMIP)
- Implementation of Weymouth equations for gas grids:
 - Weymouth constraints for the gas flows, based on nodal pressures
 - Line-pack constraints for representing gas buffer storage in the grid
 - Good LP formulation of Weymouth equations for unidirectional pipelines
 - Bi-directional pipelines best modeled with MIP only, but approximately with RMIP
- The Add-on grids facility generalized to support various kinds of grids
- For more details, see:
https://github.com/etsap-TIMES/TIMES_Documentation/blob/master/User_Notes/TIMES-Grid-Features.pdf



Schematisation of a three node network. The node N3 is defined as the slack bus. The slack bus's influence is usually nullified, making its selection insignificant to the resulting PTDF values.

User-defined Agents in the TIMES Climate Module

- For staying below 2°C with high probability, radiative forcing should presumably be limited to below 3 W/m² by 2100
- While reaching this target is increasingly challenging, one may consider adding additional explicitly represented forcing agents into energy systems modelling, at least within global-scale modelling
- Clearly, including CH₄ and N₂O are among highest priority, and hydrogen economy may emphasize the importance of forcing from CH₄ due to H₂ atmospheric chemistry
- Additional agents to consider could be F-gases (HFCs, PFCs, SF₆, NF₃), Montreal gases, and acidifying gases (SO₂, NO_x)
- However, if the emissions trajectories cannot be endogenized, one might well resort to using CM_EXOFORC like before



Source: NOAA Global Monitoring Laboratory

User-defined Agents in the TIMES Climate Module

- **New substances / agents can now be introduced**
 - Earlier, only CO₂, CH₄ and N₂O were explicitly represented (F-gases only in GWP terms)
 - Introducing some new predefined substances / agents (e.g. FGS-MT)
 - User-defined agents via CM_GHGMAP(reg,com,cg) – mapping of emissions of com to cg
 - Two-box models supported for new user-defined substances (anthropogenic / natural)
- **Several new input parameters:**
 - CM_STATS(cg,y,lim) – statistical levels for substance cg (anthropogenic / natural)
 - CM_PPM(cg) – mass units per ppm / ppb for substance cg
 - CM_DECAY(cg,lim) – annual decay of concentration (required for the anthropogenic box)
 - CM_COUPLE(cg1,y,cg2,lim) – increase in lifetime of cg2 due to cg1 (e.g. for H₂ → CH₄)
- **Other parameters work as before, also for user-defined agents**
 - CM_LINFOR can be used for defining the (linearized) forcing functions
 - CM_MAXC can be used for bounding the emissions/concentration of the new substances
 - UC_CLI can be used for referring to the concentration of the new substances in UCs
- **New default Climate Module calibration parameters (AR5)**
 - Pending input data submission from project partner UCL

Minor New Features

Minor features related to shaping process flows

- Defining non-vintaged FLO_FUNC or ACT_FLO for a **vintaged** process
 - May be useful in some cases, to override the default vintage-specific relations
 - For FLO_FUNC(cg1,cg2), can be defined by $FLO_FUNCX(reg,v,prc,cg1,cg2) = -1$
 - For ACT_FLO(com), can be defined by $FLO_FUNCX(reg,v,prc,'ACT',com) = -1$
 - Requires that the FLO_FUNC or ACT_FLO has been defined on the ANNUAL level, which is used for defining the overriding shape, according to milestone year
 - Effectively results in the relation being defined like in the **non-vintaged** case
 - Recall that an extrapolation option may also be needed for FLO_FUNCX
- Shaping of capacity-related process flows by age
 - An age-based shape can be now specified for flows defined by NCAP_COM
 - Can be used both for vintaged and non-vintaged processes
 - SHAPE index defined by $FLO_FUNCX(reg,v,prc,'CAPFLO',com) = index$
 - As usual, the shape itself is defined with SHAPE(index,age)
 - Shaping of NCAP_OCOM based on COEF_CPT now also possible, by defining $FLO_FUNCX(reg,'0',prc,'CAPFLO',com)=3$ together with NCAP_OCOM(r,v,p,com)

New

Minor new reporting features – 2 (v4.7–4.9)

- Reporting of power levels of flows slightly enhanced
 - Power levels are often of interest, obtained by dividing flows by G_YRFR
 - Requested by $RPT_OPT(nrg_type,1) = 1$, where $nrg_type \in \{ELC, GAS, LTHEAT, HTHEAT\}$
 - Now input flows can also be included (as negative values), with $RPT_OPT(nrg_type,3) = 2$
- Including past investments in the Cap_New reporting
 - May be useful for reporting total investments by period
 - Limited to NCAP_PASTI capacity investments that are within the model horizon
 - Request by setting $RPT_OPT('NCAP',7) = 1$;
- Reporting of retired capacities in detail (in Par_CapRet)
 - Normally, only the total retired capacities are reported in Var_Cap (with vintage= α)
 - Detailed report can now be requested by $RPT_OPT('CAP',5) = 1$;
- Option for outputting process units table in the GDX file
 - Experimental, based on user input on the Forum about retrieving units from the GDX file
 - Requested by the setting \$SET PUNITS YES

Most recent Minor Improvements (v4.7–4.9)

- New IE option for flushing out time series (–13)
 - Allows to remove whole time series in a scenario run (useful with VEDA scenario handling)
 - Supported for various bounding attributes (those that support IE options 10–15):
_BND, UC_RHS*T*, *_MARK, FLO_FR, FLO_SHAR
- New attribute for bounding flows in terms of power rate levels: FLO_BDLVL
 - Useful for defining bounds on e.g. all DAYNITE level timeslices with a single parameter
 - The bound value should represent the hourly maximum flow (in the flow units)
- Option for reformulating EQ(I)_FLOFR equations for performance
 - FLO_FR defines a bound fraction for a flow in timeslice, in proportion to total ANNUAL flow
 - The default formulation may result in huge equations in terms of non-zeros, when there is a large number of DAYNITE timeslices involved (e.g. 8760)
 - The reformulation is based on an ANNUAL aggregation equation plus simple timeslice-specific share equations, thereby highly reducing the amount of non-zeros
 - Activated by defining $FLO_FR(r,t,p,c,ANNUAL) = -1$;
- Adjusting the CHP reduction heat gain (if such is modeled)
 - $PRC_ACTFLO(r,v,p,com)$ can now be used for defining the reduction heat gain in proportion to the corresponding electricity loss (com = the dummy reduction flow)

Status of the ETSAP TIMES Model Generator

Current status of the model generator

Maintainer's perspective

- **Evolution of the TIMES GAMS code**
 - First versions written around 2000 (Gary Goldstein as the main code developer)
 - Design team: Gary Goldstein, GianCarlo Tosato, Richard Loulou, Amit Kanudia, Ken Noble, Uwe Remme, Peter Schaumann, Günter Schmid, Denise van Regemorter, Tom Kram, Tomas Larsson
 - The basic design appears to have quite well withstood time
 - Uwe Remme (IER) was the second primary maintainer after Gary G, accomplishing many notable improvements, and implemented e.g. the model reduction algorithm
 - After Uwe, Antti Lehtilä became the primary maintainer (around 2006 → 2025)
- **Stability of the TIMES code**
 - Bug discoveries quite few in number in recent years, and mainly on new or exotic features
 - In addition, very few requests received for additional exceptions management
 - → The core standard TIMES code appears to have become very stable
- **Performance of the TIMES code execution under GAMS**
 - Performance been continuously improved over years, and is good with most models
 - Ex: 20–30 million Eq. models with 300–2000 timeslices may generate in 6–8 minutes
 - BUT: Models with a large sets of timeslices or processes may face degraded performance

Current status of the model generator

Maintainer's perspective – continued

- **GAMS performance issue related to large domain sets**
 - Firmly identified within the ETSAP performance project in 2023–2024
 - Occurs regularly with models having over 3000 timeslices, e.g. 8760 hourly TS
 - Performance may degrade by a factor of five or even more (within **equation generation**)
 - No obvious TIMES code solution appears to exist, and neither any solution could be suggested by the GAMS experts during the project; issue appears *internal* to GAMS
 - There are some promising results identified by changing the order of the indices of some core variables and equations, but such would create backwards incompatibility
 - May need to discuss whether to pursue any such, or to urge GAMS to find a solution
- **Migration of the TIMES code to Julia or GAMSPy**
 - Migration of TIMES to an open source modeling platform has been long on the table
 - **Julia**: Complete code conversion might require substantial time and ETSAP funding
 - **GAMSPy**: Another alternative, not quite open source but would be free to use for academic users (including unlimited Cplex solver)
 - As GAMS has developed a semi-automatic translation for GAMSPy, this could be an attractive and worthy option at least for the medium term
 - GAMSPy translation may also support collaboration and any subsequent migration to Julia

Thank you!