Summary of recent TIMES enhancements
(v2.8.0 – v3.0.4)

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Fixing first periods to previous solution

- Can be very useful for freezing the model solution to the Baseline scenario for the nearest future (or at least until present)
- Requires that the Baseline solution has been saved to a GDX file
- Freezing is activated by using two GAMS control variables:
  - $SET FIXBOH <last_year_to_freeze>
  - $SET LPOINT <run_name>
- The periods can also be frozen differently by region
  - Parameter REG_FIXT(reg) defines the last_year_to_freeze
- The feature can now be also used with stochastic mode and sensitivity / tradeoff analysis
- Can even be used recursively, for a manual stepped solution
Time-stepped TIMES

- Standard TIMES is clairvoyant, i.e. has perfect foresight
- Time-stepped TIMES myopic, i.e. has limited foresight
  - Model is solved in a recursive-dynamic fashion
  - Activated by control variable $\text{SET TIMESTEP <step_length>}$
  - Additional parameter G_OVERLAP defines the step overlap

Enhancements in the TIMES Climate Module

- Non-modeled gases: exogenous forcing
  - Radiative forcing sensitivity to CO$_2$ concentration:
    \[ \gamma = 4.1 \text{ W/m}^2 \]
    or
    \[ \gamma = 5.35 \times \ln(2) \text{ W/m}^2 \]
  - Temperature sensitivity to CO$_2$ concentration: High uncertainty

Environmental constraints
Extending the climate equations beyond EOH

- **Motivation:** Climate change has considerable time lags:
  - For example, temperature will continue to rise even long after strong emission cuts
  - It can be useful to be able to set climate targets beyond EOH
- **TIMES v3.0.0 and above allow using the climate equations over any user-defined time-span beyond EOH:**
  - Requires setting EOTIME in the run file (or VEDA SysSettings)
  - Setting CM_CONST('EXT-EOH') defines an extrapolation point for the global emissions (e.g. 2150, or 0 for the EOH)
  - CM_MAXC bounds on emissions beyond that year will be considered emission projections (e.g. zero emissions in 2200)
  - CM_MAXC bounds on temperature, forcing and concentration can be defined for any years beyond EOH

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Elastic supply cost curves

- Elastic supply costs around a base quantity, for any commodity
- Could be useful by providing an automatic generation of supply cost curves for imported commodities:
  - Base price and quantity automatically transferred from Baseline
- Implemented as an extension to the Damage Cost facility of TIMES
Enhanced cumulative constraints

The following cumulative attributes are now supported:

- COM_CUMNET(reg,y1,y2,com,lim) (old)
- COM_CUMPRD(reg,y1,y2,com,lim) (old)
- ACT_CUM(reg,prc,y1,y2,lim) (new)
- FLO_CUM(reg,prc,com,y1,y2,lim) (new)
- UC_CUMACT(uc_n,reg,prc,y1,y2) (new)
- UC_CUMFLO(uc_n,reg,prc,com,y1,y2) (new)
- UC_CUMCOM(uc_n,reg,type,com,y1,y2) (new)

The ‘N’ bound type can be used for defining a horizon-dependent MULTI multiplier index for the cumulative bound.

New UC_TIME attribute can be used for defining horizon-dependent RHS constants for cumulative UC constraints.

Support for using cumulative constraints under variable horizon lengths and Time-stepped mode greatly improved!

Simplified dynamic process bound equations

Simple dynamic constraints for processes are frequently needed:
- Growth constraints for capacity / activity
- Decay constraints for capacity / activity
- Limits for new capacity installation between periods

Such constraints can be defined by the UC facility, but that may become cumbersome for a large number of similar constraints.

TIMES v3.04 and above will support defining simple process-wise dynamic constraints in an easier way, without introducing UC_N names for each constraint.

The powerful process filter and rule-based constraint facilities of VEDA-FE and ANSWER can be used for bulk creation of dynamic process constraints.

Employs UC_CAP, UC_ACT and UC_NCAP, but without RHSxxx
Miscellaneous small enhancements

- Increased flexibility in the inter-regional topology of IRE processes
- The bounds of the Objective Function component variables can now be user-defined (e.g. making variable costs a “free” variable)
  - By UC_RHS / UC_RHSR with predefined UC_N names (OBJINV, OBJFIX, OBJVAR, OBJSAL)
- Capacity-related flows can now be referred to in UC constraints:
  - Normal UC_FLO( ...) will include the cap-flows whenever UC_ATTR(reg,uc_n,side, 'FLO', 'CAPFLO') is also specified
- New G_OFFTHD parameter for fine-tuning of process availability:
  - Affects the impact of *_OFF parameters at period boundaries
- Support for using the Savage Minimax Criterion in stochastic mode
- New uncertain attribute S_FLO_CUM is available under stochastic mode (uncertain equivalent of FLO_CUM)

Reporting enhancements

- VAR_FIN / VAR_FOUT reporting at COM_TS or ANNUAL level
- Cplex Objective ranging information can be provided for VAR_NCAP variables (may take a lot of time in the solver)
- New reporting attributes:
  - Marginals and levels of cumulative process constraints
  - Marginals of inter-regional exchange equations
  - Marginals of dynamic process bound equations
  - New VAR_NCAPR attribute:
    - Benefit-Cost indicators for VAR_NCAP variables (optional)
    - Activate by control variable: $SET BENCOST YES
    - Includes the costs, benefits, competitiveness gap and ratio
    - Includes the Cplex ranging information (if activated)
- ANSWER-TIMES reporting now supports stochastic mode
Issues with Storage

- Original TIMES formulation allows arbitrary by-pass flows through storage processes in each timeslice / period.
- This may cause problems for market-share constraints or other bounding constraints (especially through VAR_COMPRD).
- In TIMES v3.0.4 the issue can be addressed in the following ways:
  1. Define the stored commodity only as an Output or Input (TOP):
     - Storage input and output flows will then appear either only on the production side or only on the consumption side of the commodity balance equations.
     - Backwards compatibility by using both IN+OUT (or none).
  2. The output flow can be limited to the maximum amount that could be discharged from the storage, using FLO_SHAR:
     - FLO_SHAR(reg, y, prc, com, 'ACT', 'ANNUAL', 'UP')
- Additional issue related to peaking constraints needs to be resolved.

TIMES Matrix Tools (Courtesy of IER)

- The Matrix Tools are a stand-alone set of utilities for analysing the primal and dual equations and solutions of TIMES models.
- The tools can be used for producing comprehensive reports about:
  - the LP matrix coefficients, by constraint or variable.
  - the primal and dual solution.
  - combined solution attributes that can be used for analyzing the components of the dual constraints for primal variables.
  - value flows and benefit / cost ratios for decision variables.
- The Matrix Tools are thus the ultimate tool for full-blown solution analysis, including detailed value flows and benefit-cost indicators.
- An excellent tool for pedagogical purposes.
- Shortcomings: Large results database, no ranging information.
Conclusions

- Practically all significant MARKAL features are available in TIMES
  - Some features nonetheless missing from TIMES, including: Early retirement of technologies, Net emissions accounting, SAGE market share algorithm, and MGA
- The standard TIMES code appears to have reached a good level of stability and robustness

![The latest TIMES version v3.0.4 will be publicly released by end of June](image)

- A number of further enhancements have been suggested, for example:
  - Report the levelised costs of technologies by vintage (or period?)
  - Incorporate full ranging information into TIMES results
- Advanced TIMES users are encouraged to implement useful new features and contribute them into the common ETSAP code base!