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The TIMES model generator: Status of the code

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Development
- By ETSAP
- Implementation in GAMS

TOOLS
- VEDA-FE (Front End)
- VEDA Analyst

TIMES

(The Integrated MARKAL EFOM System)

Methodology
- Bottom-up Model
- Perfect competition
- Perfect foresight
- Optimisation (LP/MIP)

Min/Max Objective function
s.t.
Equations, Constraints
Decision Variables <=> Solution
Input parameters

Features
- Multi-region
- Inter-temporal
- Elastic demands
- Vintaging
- Load curve
- Endogeneous learning

Features of TIMES

- Flexible process description:
  - General process description with three process types: general processes (PRC), exchange processes (IRE) and storage processes (STG)
  - Ratios of input and output flows can be determined by optimization
  - Time slice operation according to commodity requirements
  - Direct access to all flow variables (e.g. for usage in user constraints, to associate emissions with fuels)
- Full vintaging of processes (optional by process):
  - Technical parameters of a process as a function of the vintage year
  - Shaping / decay of input parameters as a function of age
- User-controllable inter-/extrapolation of input data to model years:
  - Linear and log-linear interpolation, direct extrapolation or fill-in with EPS
  - Default rules if no options specified
- More accurate cost representation:
  - Annual cost accounting
  - Spread investment builds and payment
  - Investment leads (e.g., R&D and construction) and decommissioning
  - Splits of O&M components (e.g., labor)

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Features of TIMES (contd.)

- High independence of data vs. model years achieved
- Flexible time periods:
  - Unequal period duration
  - Technical parameters of a process can be defined over a two-dimensional space of time (vintage × age)
  - Past investments based on vintage year not residual curves
- Flexible definition of time slices:
  - Three levels (seasonal, weekly, daynite) with an arbitrary number on each level
  - All time slice levels are available for all processes and commodities
  - Storage and load shift processes may operate between any time slices
- Flexible discounting options:
  - Technology-dependent discount rates, economic vs. technical lifetimes
  - Time-dependent discount rates at sector/technology level if desired
  - Optional mid-year discounting (default: beginning-of-year discounting)

Features of TIMES (contd.)

- User constraints:
  - All variables can be used in a user constraint
  - Possibility to define inter-temporal constraints
  - Possibility to define cumulative constraints over region or period
  - Option to formulate growth constraints
- Option to use elastic demands (linear staircase formulation)
- Endogenous technological learning (MIP approach, technology clusters)
- Option to define discrete capacity extensions (lumpy investments)
- Mechanisms to add extensions (model equations/variables, report routines) that can be turned-on/off (e.g. VTT, IER extensions)
- Connection to VEDA-BE via GAMS GAMS2VEDA utility (allowing user augmentation for addition data dumps including input data)

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Recent modifications in the TIMES code

- Performance improvements (e.g. investment costs calculated in a similar fashion as salvage value)
- Bug fixes (e.g. ETL, elastic demand, objective function)
- Linkage with VEDA4-BE (primal variables, costs by type and prc/com, reduced costs, shadow prices of commodity balance and peaking eqn)
- Enhancements of the code:
  - Time-dependent discount rates
  - Option to use discrete capacity extension
  - Improvements in user constraints: easier formulation for growth constraints and addition of import/export flows as possible variables

Discrete capacity extension

- Discrete capacity extension:
  - Capacity can only be added in different predefined block sizes resulting in a MIP problem
  - Blocks may have different specific investment costs, e.g. specific costs decrease with the block size

$$VAR\_NCAP_{r,v,p} = \sum_j VAR\_NDSC_{r,v,p,j} \cdot ncap\_disc_{r,v,p,j}; \forall\, rtp_{r,v,p}$$

$$\sum_j VAR\_NDSC_{r,v,p,j} = 1\ ; \forall\, rtp_{r,v,p} \quad (\Leftrightarrow \text{SOS1 set supported by some solvers})$$

$$VAR\_NDSC_{r,v,p,j} \in \{0;1\}$$

j: index for binary variables

$VAR\_NDSC_{r,v,p,j}$: binary variable

$ncap\_disc_{r,v,p,j}$: allowable sizes of capacity extensions

Formulation of growth constraints

- **Based on user constraints**
- **Possibility to define not only growth constraints but also phase-out constraints**
- **Growth constraints applicable to all variables**
- **More than one technology may be involved in a growth constraint, e.g.:**

$$VAR\_CAP_{r,t,TechA} \le gr_{r,t,TechA}^{M_t - M_{t-1}} VAR\_CAP_{r,t-1,TechA} + gr_{r,t,TechB}^{M_t - M_{t-1}} VAR\_CAP_{r,t-1,TechB} + const.$$

Performance of a multi-regional TIMES model

- **Single region model**
  - **# processe: 986**
  - **# commodities: 411**
  - **# periods: 11**
  - **# timeslices: 4 (WD, WN, SD, SN)**
- **Each region is connected to all other regions by an exchange process (-> 105 exchange processes in the 15 region model, 300 in the 25 region model)**

		1 region	15 regions	20 regions	25 regions
Reduced matrix	# rows	30,828	467,611	625,696	784,925
	# columns	25,234	387,826	521,516	657,450
	# nonzeros	230,532	3,487,429	4,663,164	5,845,675
Memory usage before solver is called [MB]		70	944	1261	1582
Computation time [sec]	Execution	13	347	542	781
	Matrix generation	22	331	455	625
	Barrier time	27	509	746	1678
	Crossover time	4	227	490	1147
	Reporting	14	270	394	580
	Total	**80**	**1684**	**2627**	**4811**

(using GAMS21.3, CPLEX9.0, Pentium 4, 3.2 Ghz, 2 GB RAM)

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Features implemented by IER and VTT that could be considered for adoption in the common code

- **Market/product allocation constraints (IER, VTT)**
  - **Useful for calibrating / constraining market shares etc.**
- **Back-pressure / condensing mode availability of CHP processes (IER)**
  - **Useful for realistic representation of CHP heat production**
- **Commodity-dependent availability factors (VTT)**
  - **Useful for e.g. realistic representation of CHP heat production**
  - **Has been included as pending in the system documentation**
- **Generalized constraints for process flows (VTT)**
  - **Useful for modeling of many specific process characteristics**
- **Extended shaping parameters for vintaged processes (VTT)**
  - **Age-dependent emission factors and efficiencies**
- **… etc. (IER, VTT, …)**

Future work

- VEDA-FE/TIMES evolution
- Documentation
  - System documentation
  - User guide, with process examples by type
  - Full sample model, including VEDA-BE tables
- Enhanced Quality Control of input data
- Streamlining of GAMS code
- Simplification of some basic input parameters (GAMS / VEDA-FE)
- Further enhancements of the methodology:
  - TIMES/MACRO
  - Stochastic programming
  - MARKAL features of interest