

MARKAL Software Advancements: Status & Issues

Gary A. Goldstein, International Resources Group
Amit Kanudia, KanORS Consulting
Ken Noble, ABARE

ETSAP Annex VIII Semi-annual Workshop
IIASA, Vienna, Austria
23-27 June 2003



Major Developments: Single-Region Modeling and General

- MARKAL-Goal Programming & Trade-Off Analysis
- Lumpy Investments (MIP)
- VEDA4
- Other Substantive Adjustments
- Miscellaneous Corrections
- Pending



Major Developments: Multi-region Modeling & Future

- Overview of Trade
- SAGE
 - Running and log files
 - MKTSHR market share algorithm
 - SETL (stepped) endogenous technology learning
 - VEDA-SAGE
- ETP
 - ENV_ENT Emissions Trading
 - DMD_Vint technology vintaging
 - ANSWER-ETP
- Considerations for the Future



MARKAL Goal Programming

- Multi-criteria optimization, minimization of the deviation from the specific numeric goal set
- **Nonpreemptive**, assumes that all of the goals are of approximately equal importance to a decision maker, with weights determining the rate at which they can be traded off
- (Emissions) Trade-off sensitivity facility
- Full documentation as to formulation, data requirements and use (GoalProgramming_New.DOC)
- Research Funded by EPA-OAP



MARKAL Goal Programming – Data

$GPENV$ = list of emission indicators subject to evaluation	[$GPENV$]
$escal_e$ = scaling factor for each emission (default = 1)	[$GPEMSCL$]
$cscal$ = scaling factor for total cost (default = 1)	[$GPCSTSCL$]
ewt_e = weighting factor, above/below, for each emission (default = 1)	[$GPEMWTA/ B$]
cwt = weighting factor, above/below, for total cost (default = 1)	[$GPCSTWTA/ B$]
$cap_{e,t}$ = emission levels from the reference case	[GP_CAP]
$cappct_e$ = fraction by which to reduce cap_e	[$GPEMPCT$]
$least_cost_t$ = cost of least cost solution from the reference case	[GP_LC]
$gpstart$ = year from which the GP emissions & cost limits are applied	[$GPSTART$]



MARKAL-GP Multi-criteria Formulation

- Activation switch \$SET GP 'REF' or 'YES'
 - 'REF' solves MARKAL(ED), and writes the period costs and emission levels to GPRUNS.DD
 - 'YES' solves using the Multi-criteria formulation (below), adding case name and emission levels to GPRUNS.DD

➤ Min

$$((100/cap) * ewt * d_1^+ + (100/least_cost) * cwt * d_2^+)$$

➤ Such that

$$\sum_{f \in F} e_f x_f + d_1^- - d_1^+ = cap$$

$$\sum_{f \in F} c_f x_f + d_2^- - d_2^+ = least_cost$$



MARKAL-GP Emission Trade-off Runs

- Activation switch \$SET GP 'T-O'
- Data requirements (in file named GPRUNS.GP)
 - Perturb list of cases (GP_RUNS)
 - List of emissions (GPENV)
 - Emissions levels (GP_AEM(gp_runs,gpenv,tp))
- Trade-off sensitivity facility
 - Loop over each GP_RUNS case
 - Emission fixed to GP_AEM levels for current case
 - MARKAL(ED) SOLVEd
 - ANT (for each case) and VEDA (all to <T-O> run name) results dumped



MARKAL-GP Trade-off File - Reference

```
$ONMULTI
* GP emissions
  SET GPENV /
    CO2
  /
* REF Total Discounted Annualized Costs
  PARAMETER GP_LC /
    1990          6623799.3716
    2000          4444725.9340
    2010          2915710.6344
    2020          1783621.4671
  /
* REF Emission Levels
  PARAMETER GP_CAP /
    CO2.1990      1327000.0000
    CO2.2000      1300000.0000
    CO2.2010      1300000.0000
    CO2.2020      1300000.0000
  /
* REF Emission Marginals
  PARAMETER GP_EMRC /
    CO2.1990      -0.0618
    CO2.2000      -0.0507
    CO2.2010      -0.0652
    CO2.2020      -0.1476
  /;
```



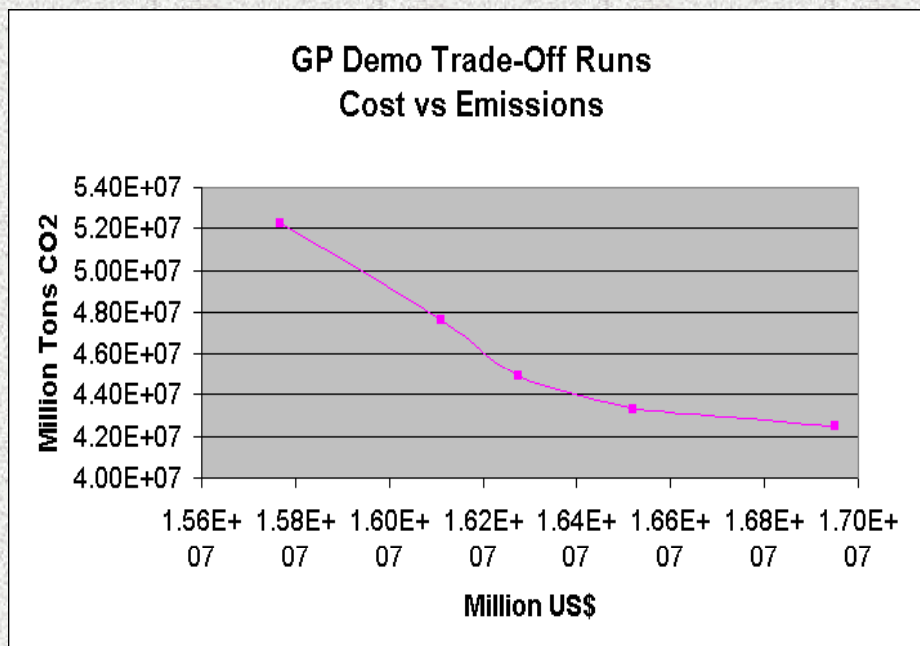
MARKAL-GP Trade-off File – GP Run

```

* GP Run Case
  SET GP_RUNS /
    DEMGP4X /
*-----*
* DEMGP4X GP Input Parameters      Below      Above      Scale Factor      Percent
*      Costs                       0.2000     0.2000       1.0000
*      Emission: CO2                0.8000     0.8000       1.0000             0.4000
* DEMGP4X Target Emission Levels
*      CO2.1990                      796200.0000
*      CO2.2000                      780000.0000
*      CO2.2010                      780000.0000
*      CO2.2020                      780000.0000
*-----*
* DEMGP4X GP Cost Variables
*      1990                          0.0000      862703.1523
*      2000                          0.0000      352961.7003
*      2010                          0.0000      859391.3457
*      2020                          0.0000      248645.7638
* DEMGP4X GP Emission Variables
*      CO2.1990                      0.0000      410225.9101
*      CO2.2000                      0.0000      333501.2767
*      CO2.2010                      0.0000      122942.7462
*      CO2.2020                      0.0000      116623.5689
* GP Run Emission Levels
  PARAMETER GP_AEM /
    DEMGP4X.CO2.1990                 1206425.9101
    DEMGP4X.CO2.2000                 1113501.2767
    DEMGP4X.CO2.2010                  902942.7462
    DEMGP4X.CO2.2020                  896623.5689
  
```



MARKAL-GP Trade-off Run Results



Lumpy Investments (MIP)

- ABARE undertaking funded by AUSAID ASEAN project
-



VEDA4 New Features

- Evolutionary advancement of VEDA3 (faster, more powerful filtering, combined set/member tabs, ...)
- Development spurred and push (and supported) by needs evolving at EIA for SAGE
- More generalized delimited file format for input files
- GAMS VEDA Data Definition (VDD) and dump utility, GDX2VEDA
- Spreadsheet “reader” to enable dynamic construction of the VEDA dump files



VEDA4 Applications in Place

- SAGE/MARKAL (using custom report writer, pending TD resolution in GDX2VEDA; once ready user could adjust VDD to dump input data)
- MERGE5 (w/ descriptions and subsets pending GDX2VEDA/GDXMERGE resolution or separate Set dump module)
- EGRID2002 spreadsheet extraction
- Various GAMS LIB models (via GDX2VEDA)
- Hill Associates GAMS utility model (via GDX2VEDA in the works)



VEDA4 Header – MARKAL/TIMES

```
*ImportID          - Scenario: DUTEST
*VEDAFlavor        - MARKAL/TIMES
*Dimensions        - Attribute;Commodity;Process;Region;Scenario;TimePeriod;
                  TimeSlice;Vintage;DV;PV
*ParentDimensions - Process: Region; Commodity: Region
*FieldSize         - Attribute:20;Commodity:10;Process:10;Region:10;Scenario:10;
                  TimePeriod:10;TimeSlice:10;Vintage:10;DV:12;PV:12
*SetsAllowed       - Commodity;Process
*UnitsID           - Attribute
*NotIndexed        - DV;PV
*ValueDim          - DV;PV
*DefaultValueDim   - PV
*FieldSeparator    - ,
*TextDelim         - "
```



VEDA4 Delimited VD File - MARKAL/TIMES

```

---
"VAR_CAP", "-", "T47", "DEMO", "DUTEST", "2020", "-", "-", 6.2130, 1300.0000
"VAR_CAP", "-", "T4E", "DEMO", "DUTEST", "2020", "-", "-", 71.3434, 10.0000
"VAR_CAP", "-", "T4F", "DEMO", "DUTEST", "2020", "-", "-", 12.9271, 1886.0000
"VAR_CAP", "-", "T4X", "DEMO", "DUTEST", "2020", "-", "-", 0.0000, 0.0000
"VAR_CAP", "-", "T4Y", "DEMO", "DUTEST", "2020", "-", "-", 0.0000, 12653.0000
"VAR_CAP", "-", "T9H", "DEMO", "DUTEST", "2020", "-", "-", 0.0000, 6898.0000
"VAR_FIN", "COA", "E01", "DEMO", "DUTEST", "1990", "-", "-", 0.0000, 17886.6516
"VAR_FIN", "DST", "E10", "DEMO", "DUTEST", "1990", "-", "-", 0.0000, 418.0491
"VAR_FIN", "DST", "E14", "DEMO", "DUTEST", "1990", "-", "-", 0.0000, 84.5266
"VAR_FIN", "NGA", "E14", "DEMO", "DUTEST", "1990", "-", "-", 0.0000, 84.5266
"VAR_FIN", "LWR", "E21", "DEMO", "DUTEST", "1990", "-", "-", 0.0000, 2101.4581
"VAR_FIN", "ELC", "E30", "DEMO", "DUTEST", "1990", "-", "-", 0.0000, 154.6927
"VAR_FIN", "NGA", "E4G", "DEMO", "DUTEST", "1990", "-", "-", 0.0000, 94.4282
---

```



VEDA4 - MERGE5 Coal Related Results

Table Details		All tables with Coal																	
Table Description		Original Units: Active Unit																	
Scenario		Period																	
Attribute	Case	Region	2000	2005	2010	2015	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	
carbfuel	150	-	2.09	2.32	2.39	2.50	2.52	2.74	3.39	3.41	3.13	2.56	2.09	1.71	1.39	2.09	1.94		
	CAT	-	2.09	2.41	2.55	2.71	2.73	2.20	2.76	3.92	4.66	4.09	3.38	2.76	2.80	2.58	2.33		
	CST	-	2.09	2.43	2.59	2.77	2.79	2.45	2.90	4.19	5.49	6.19	5.78	4.95	4.27	3.71	3.26		
	CTI	-	2.09	2.31	2.38	2.51	2.54	2.80	3.62	4.29	4.56	3.95	4.66	6.11	5.22	4.49	3.86		
	PPTO	-	2.09	2.43	2.60	2.78	2.81	2.49	2.94	4.21	5.71	6.42	5.94	5.07	4.14	3.39	2.77		
	REF	-	2.09	2.46	2.66	2.93	3.03	2.99	4.21	5.57	7.46	10.54	13.25	15.85	17.94	19.17	19.64		
	SAT	-	2.09	2.44	2.63	2.87	2.90	2.60	3.25	4.36	6.06	7.87	10.00	11.53	10.71	8.98	7.56		
	lati	-	2.09	2.42	2.58	2.73	2.75	2.40	2.95	4.14	5.94	7.35	9.06	10.32	8.66	7.29	5.96		
fossilprod	150	canz	3.70	4.48	4.64	5.48	5.31	6.71	6.00	4.52	3.70	3.02	2.47	2.02	1.65	2.82	2.64		
		china	20.30	23.31	26.27	29.21	30.56	40.34	53.53	60.18	57.37	46.88	38.30	31.30	25.57	40.29	37.55		
		eefsu	13.90	13.90	13.90	13.90	13.90	11.55	12.78	9.48	7.75	6.33	5.17	4.23	3.45	10.11	9.94		
		india	6.40	7.02	7.47	7.98	8.27	12.28	17.55	21.15	20.86	17.05	13.93	11.38	9.30	12.27	11.13		
		japan	2.70	2.70	2.68	2.67	2.66	1.44	0.20	0.15	0.12	0.10	0.08	0.07	0.06	0.21	0.21		
		mopec	2.00	3.25	3.13	3.03	2.93	2.61	2.40	3.26	2.66	2.18	1.78	1.45	1.19	2.27	2.17		
		row	8.80	9.87	9.76	9.67	9.59	19.45	34.65	34.95	30.87	25.23	20.61	16.84	13.76	12.35	10.36		
		usa	19.10	19.10	19.10	20.12	20.02	11.87	10.16	5.04	4.11	3.36	2.75	2.24	1.83	4.00	3.84		
		wEUR	9.60	12.39	11.99	11.63	11.30	7.44	3.35	2.73	2.23	1.83	1.49	1.22	1.00	2.47	2.41		
		world	86.50	96.01	98.96	103.70	104.54	113.69	140.62	141.47	129.69	105.96	86.58	70.74	57.80	86.79	80.26		
		CAT	canz	3.70	4.82	5.47	6.34	6.09	4.72	7.62	10.08	11.25	9.53	7.79	6.36	6.04	5.27	4.64	
			china	20.30	23.76	27.47	31.60	33.64	34.32	47.85	61.72	69.05	61.05	49.89	40.76	44.81	41.46	38.51	
			eefsu	13.90	13.90	13.90	13.90	13.90	11.55	10.37	9.20	9.20	9.20	9.20	7.52	9.20	11.71	11.25	
			india	6.40	7.17	7.86	8.78	8.99	8.05	13.43	18.83	22.21	19.26	15.73	12.86	13.26	11.94	10.86	
			japan	2.70	3.01	2.97	2.93	2.90	1.63	0.98	0.34	0.32	0.30	0.24	0.20	0.26	0.25	0.24	
			mopec	2.00	3.67	3.51	3.37	3.24	2.87	2.61	2.39	2.26	5.00	4.09	3.34	3.51	3.23	2.96	
			row	8.80	10.77	11.24	11.01	10.80	6.76	16.99	37.05	50.76	41.74	34.10	27.86	23.43	19.41	16.13	
		usa	19.10	20.30	20.80	22.17	21.88	13.38	8.97	19.27	24.73	20.78	16.98	13.87	12.76	10.99	9.55		
		wEUR	9.60	12.64	12.52	12.11	11.73	7.79	5.62	3.53	3.28	2.68	2.19	1.79	2.64	2.54	2.47		

VEDA4 - EGRID XLS Data Extraction

The screenshot shows the Microsoft Excel interface with the 'eGRID2002 Version 2.01 Plant File (Year 2000 Data)' spreadsheet. A 'Create File...' dialog box is open, allowing the user to select specific attributes for data extraction. The dialog box lists the following attributes:

- SEQPLT00: eGRID2002 2000 file plant sequence number
- SEQPLT99: eGRID2002 1999 file plant sequence number
- PSTATABB: State abbreviation
- PNAME: Plant name
- ORISPL: DOE/EIA ORIS plant or facility code
- PLTYPE: Plant type
- PREVUTIL: Previously a utility plant flag
- CHANGE: Change? If Y, go to EGRDPLCH file
- OPRNAME: Plant operator name
- OPRCODE: Plant operator ID
- UTLSRVNM: Nonutility's service area name
- UTLSRVID: Nonutility's service area ID
- OPPRNUM: Location (operator)-based parent company ID
- OPPRNAME: Location (operator)-based parent company name
- PCANAME: Location (operator)-based power control area name
- PCAID: Location (operator)-based power control area ID
- NERC: Location (operator)-based NERC region acronym
- NERCNUM: NERC number associated with NERC region
- SUBRGN: eGRID subregion acronym
- SRNAME: eGRID subregion name

VEDA4 - EGRID NE Plant Data

Veda Tables - [NE_Data]

Table Description: Add New England Data

Original Units: Active Unit

County *NERCNUM* *PCAIID* *PlantType* *PumpStorage* *Scenario* *SOURCEM*

PrimaryFuel	State	PlantCode	CO2Rate	Capacity	CapFact	HeatRate	HgRate	Latitude	Longitude	NetGen	PWRTOHT	SO2Rate
BIOMASS	CT	563	86.58	257.40	0.20	542.31	0.00	41.81	72.73	442,115.00	0.00	0.16
		589	227.80	50.00	0.33	16,806.05	0.00	44.49	73.21	146,375.00	0.00	0.01
		54085	152.64	108.00	0.79	11,095.53	0.00	45.59	69.91	745,046.80	0.00	0.67
BL	ME	54085	5.71	80.00	0.86	5,343.93	0.00	45.06	70.38	605,805.30	0.00	0.73
		54587	114.15	6.50	0.67	170,807.53	0.00	45.52	68.85	37,840.50	0.00	16.03
		10675	2,128.59	213.90	0.81	10,328.11	0.00	41.49	72.13	1,525,784.10	0.00	1.99
COL	CT	568	2,132.96	679.14	0.36	11,287.74	0.00	41.17	73.18	2,162,790.00	0.00	9.93
		10417	1,238.27	5.69	0.70	6,006.66	0.00	42.17	72.60	34,783.80	0.00	11.72
		1606	2,205.43	136.00	0.81	10,747.74	0.00	42.28	72.61	967,683.00	0.00	17.40
	MA	1613	2,396.23	216.11	0.41	11,763.93	0.00	41.73	71.13	768,955.00	0.00	12.14
		1619	1,996.93	1,619.35	0.58	9,997.87	0.00	41.71	71.19	8,295,544.00	0.00	11.29
		1626	2,224.74	805.25	0.58	12,226.24	0.00	42.53	70.88	4,115,752.20	0.00	16.66
		10495	1,858.96	102.00	0.79	10,816.71	0.00	44.57	70.65	704,659.90	0.00	1.99
NH	2364	2,264.40	496.40	0.65	11,035.77	0.00	43.14	71.47	2,835,080.00	0.00	24.64	
	2367	2,671.78	171.25	0.47	13,125.19	0.00	43.10	70.79	698,667.00	0.00	15.24	
DI	MA	10553	3,455.71	1.05	0.01	21,645.02	0.00	42.36	71.90	115.50	0.00	5.23
		54870	1,357.06	3.41	0.16	0.00	0.00	43.36	72.19	4,802.00	0.00	0.22
FO1	MA	10522	1,945.83	41.87	0.33	12,430.91	0.00	42.45	71.46	122,311.70	0.00	3.52
		10823	248.69	58.40	0.03	0.00	0.00	42.34	71.06	14,957.90	0.00	0.01
		10883	1,290.33	62.80	0.34	8,062.02	0.00	42.34	71.06	189,390.70	0.00	2.49
	NH	1585	2,810.64	284.00	0.00	17,604.57	0.00	42.15	71.20	765.30	0.00	3.86
		1586	2,725.04	42.60	0.00	17,068.41	0.00	42.45	71.46	1,170.10	0.00	4.75
		1592	2,708.75	135.15	0.01	16,966.40	0.00	42.15	71.20	6,150.60	0.00	4.58
		54992	1,932.85	2.75	0.41	12,503.92	0.00	42.45	71.46	9,898.90	0.00	7.24
		10108	679.81	6.97	0.47	4,354.99	0.00	43.01	71.08	28,532.30	0.00	0.98
		54293	1,352.38	4.80	0.28	8,470.68	0.00	42.95	71.85	11,938.40	0.00	2.10

Recent Substantive MARKAL Adjustments

- Move to GDX-based GAMS implementation
 - GDX (GAMS Data Exchange) is the GAMS data management trend for the future
 - GAMS20.5 and above result in compile error for multi-region model runs
 - CMD drivers to isolate GDX from older (BAT) approach
 - All future GAMS developments GDX based
- VEDA4 compatible results dump
 - \$SET VEDABE 'YES'
 - \$SET VEDABEX 'V4'



Recent Substantive MARKAL Adjustments (Cont.)

- Change EQ_CPT(con/prc) to =L= under user control
 - Needed due to affects of RESID on marginals (see Tosato memo MARKALtech_note1.DOC + RESID-XLMEError.XLS)
 - \$SET CPTEL 'E', default; 'L' to change the sense of the equation in the GEN and/or SLV file
 - Switching to =L= will impact results
- TCH_LIFE = 1 period if any cost provided [may impact results]
- CMD sub-system totally Path independent



Recent MARKAL Corrections

- Reporting of total discounted costs in Table 2
D..INVS/INVD/TOTSY corrected, later Total column properly matches OBJ
- Reporting of the marginal cost on investments (INVEST.M in the ANSWER INV table and VEDA)
- Stochastics
 - MS_CUM sw2 was missing pre-STAGE_2 sw1 entries
 - LAG requires sw1 entries in MS_BAL t=STAGE_2
 - LED requires MS_BAL for all stages at t=STAGE_2-1??



Recent MARKAL Corrections (Cont.)

- Minor Fixes
 - GWP accounting corrected for multi-region runs
 - Correct handling of trade costs (dump SEP_COST but include ETRANINV/OM and DELIV)
 - TSEPE bilateral trade contribution to the peak /QHR(z,'D') to convert to power
 - RAT_ACT for XLM/XPR needed to be /TE
 - RWCAP OUT.ANNUAL/CAP.UNUSEDxlm fixed
 - Shorten T_ETRANINV_R/etc to 10char (so no GAMS error with older versions)
- ENV_COST vs ENV_BOUND results (vanR, see Tosato memo of 4/24 CO2bounds-vs-cost.DOC)



Pending MARKAL Fixes

- DISCRATE needs to be re-validated (Stocks)
- LNK consumption entries into the PEAK equation should be based upon CAP, not electricity consumed (Tosato MARKALtech-note2.DOC)
- Address stray LNK when no AF(Z)(Y) (Smekens)
- Report DMD ENV_ACT/CAP separately in emissions tables (Smekens)
- T04 IMP/NETELC.TOT off (Stocks)



Pending MARKAL Fixes (Cont.)

- Stochastics
 - Resolve the remaining LED/LAG problem(s) with the US model
 - Sort out possible CUMMAX bug (Smekens + PSI)
 - T02 INVS/D rows need to reflect ETL investment costs (Smekens)
 - Sort out ETL+Stoch A3/5 differences (Smekens)



Pending MARKAL Adjustments

- Allow pumped storage (STG) to be DCN (micro-hydro)
- Review COSTBEN to make sure all recent enhancements are properly reflected
- Change to GDX2VEDA for VEDA-link, and document so modelers can add other parameters (e.g., input)
- Add \$SET ANSRSLTS 'NO' control of RW when only using VEDA
- Adjust =N= row handling
 - Drop those not referenced in reports
 - “build” in the reports instead



Pending MARKAL Adjustments (Cont.)

- IES would like to see bounds applied LO, UP, FX; rather than LO, FX, UP as is the case now
- ETL reporting across regions
- Expand DMD_Vint to include CF and O&M
- Enable multi-region stochastics (current coding prohibits)

- COMPLETING DOCUMENTATION of All Variants



Requests for MARKAL Enhancements: Expanded Emissions Report

- Goal, to associate electricity emissions with demand devices
- $TOTAL_ENV_CONV(T)$ = total emissions from conversion technologies in period T
- $TOTAL_ELC(T)$ = total PJ of ELC produced in period T
- $ENV_CON(T) = TOTAL_ENV_CONV(T) / TOTAL_ELC(T)$ gives us emissions per PJ (in period T).
- For each DMD that uses electricity:
 - PJ of electricity consumed by DMD(T) * $ENV_CON(T)$
- So instead of attributing emissions to CONs, we can instead attribute emissions to DMDs that use ELC.



Major Developments: Multi-region Modeling & Future

- Overview of Trade
- SAGE
 - Running and log files
 - MKTSHR market share algorithm
 - SETL (stepped) endogenous technology learning
 - VEDA-SAGE
- ETP
 - ENV_ENT Emissions Trading
 - DMD_Vint technology vintaging
 - ANSWER-ETP
- Considerations for the Future



Overview of Trade

- Global Trade of Energy, Material and Emissions
 - New variable and constraint
- Bi-lateral Trade of Energy and Materials, and time-sliced electricity
 - Existing variable for annual trade
 - New variable for time-sliced electricity
 - New linking and summing (for time-sliced electricity) constraints
- Shells' Trade Components
 - ANSWER V5.2
 - VEDA-SAGE



Global Trade Data

Sets & Parameter (Indexes)	Units/ Range & Defaults	Instance (Required/Omit/ Special Conditions)	Description
G_TRADE (enc/mat/env)			Any commodity, including emissions but excluding electricity, that is to be traded globally.
REG_XCVT (r,enc/mat/env)	<ul style="list-style-type: none"> • Scalar. • Default = 1. 	<ul style="list-style-type: none"> • Provided if different commodity units exist in a region. 	<ul style="list-style-type: none"> • Multiplier applied when balancing a globally traded commodity. • Applied to the global trade (R_GTRD) variable for the region in the global trade equation (MR_GTRD).
REG_XMONY (r)	<ul style="list-style-type: none"> • Scalar. • Default = 1. 	<ul style="list-style-type: none"> • Provided if different monetary units exist in a region. 	<ul style="list-style-type: none"> • Multiplier applied in the objective function to each globally traded commodity. • Applied to the global trade (R_GTRD) variable for the region in the objective function (MR_PRICE for MARKAL, MR_MTSOBJ for SAGE).
TRD_BND (r,enc/mat/env,bd,t)	<ul style="list-style-type: none"> • Units of the commodity. • No default. 	<ul style="list-style-type: none"> • Provided if a bound is to be applied. 	<ul style="list-style-type: none"> • Limit on the import or export of a globally traded commodity into/from a region. • Applied to the global trade (R_GTRD) variable for the region, period and import/export operation.



Global Trade Data (Cont.)

TRD_COST (r,enc/mat/env,b d,t)	<ul style="list-style-type: none"> • Base year monetary units. • [open]; default = 1. 	<ul style="list-style-type: none"> • Provided if a transaction or transportation cost is to be added to the cost of a bi-lateral and/or globally traded commodity. 	<p>Additional (transaction) cost associated with global trade in a commodity.</p> <ul style="list-style-type: none"> • Applied to the import/export (R_TSEP) and global (R_GTRD) trade variables in the regional objective function (MR_PRICE/MTSOBJ).
TRD_FROM (enc/mat/env)	<ul style="list-style-type: none"> • Year. • [open]; default = 1st. 	<ul style="list-style-type: none"> • Provided if trade in a global commodity is not to start in the 1st period. 	<p>Year from which global trade in a commodity may commence.</p> <ul style="list-style-type: none"> • The global trade constraint (MR_GTRD) is only generated beginning from the TRD_FROM period. • Entries for the global trade variable (R_GTRD) are only made in the associated balance (MR_BAL_G/E) and emissions (MR_TENV) equations beginning from the TRD_FROM period.



Global Trade EQ & VAR

Variables & Equations (Indexes)	Nature	Description
MR_BAL_G/E (r,t,enc/mat)	Add Variable	The balance equation ensures that the production of each commodity equals or exceeds the total consumption of said commodity. When the commodity is an energy carrier (enc), then the MR_BAL_G constraint permitting production to exceed consumption is applied. When the commodity is a material (mat), then the MR_BAL_E constraint applies which forces production to match consumption. The trade variable (R_GTRD) enters the equation is +/- for imports/exports. [Note that for imports any commodity overall transmission loss is applied.]
MR_GTRD (t,enc/mat/env)	New	The balance of the globally traded commodities between all the producers and consumers of said commodities.
MR_PRICE (r)	Add Variable	The MARKAL clairvoyant total discounted system cost for each region, summed to the objective function. The trade cost (TRD_COST) is applied to trade variable (R_GTRD).
MR_MTSOBJ (r)	Add Variable	The SAGE time-stepped minimum annualized system cost for a region, summed to the objection function, and solved successively for each period of the model run. The trade cost (TRD_COST) is applied to trade variable (R_GTRD).
MR_TENV (r,t,env)	Add Variable	The total amount of emissions generated in each period from all sources (resources and technologies) of said emissions indicator. The trade variable (R_GTRD) enters the equation is +/- for imports/exports.
R_GTRD (r,t,enc/mat/env,ie)	New	The total amount of a globally traded commodity imported/exported to/from a region.



Bi-lateral Trade Data

Sets & Parameter (Indexes)	Units/ Range & Defaults	Instance (Required/Omit/ Special Conditions)	Description
BI_TRDENT (r,e,r,e,p)			<p>The 2-tuple of region/commodity involved in bi-lateral trade. For each commodity an associated import/export supply option (srcencp) must also be specified for the same price set (p). Note that the trade is unidirectional, that is only from export to import region.</p> <ul style="list-style-type: none"> Controls the generation of the bi-lateral commodity trade constraint (MR_BITRD) between two regions.
BI_TRDELCT (r,elc,r,elc,p)			<p>The 2-tuple of region/electricity involved in bi-lateral trade of electricity by season/time-of-day. For each form of the electricity energy carrier an associated import/export supply option (srcencp) must also be specified for the same price set (p). Note that the trade is unidirectional, that is only from export to import region, and that it only occurs for the time-slices specified.</p> <ul style="list-style-type: none"> Controls the generation of the bi-lateral electricity trade constraint (MR_BITRDE) between two regions for the time-slices specified. The time-sliced electricity trade variable (R_TSEPE) is set equal to the traditional trade variable (R_TSEP), which is then used in the objective function, emission constraints, etc.; the seasonal variable appears directly in all the electricity specific constraints (MR_BALE, MR_BAS, MR_EPK), as well as the objective function (MR_PRICE/MTSOBJ).



Bi-lateral Trade Data (Cont.)

BI_TRDCST (r,ie,ent,p)	<ul style="list-style-type: none"> Monetary units. [open]; no default. 	<ul style="list-style-type: none"> Omit if not desired. 	<p>The additional “transaction” cost for bilateral trading a particular commodity.</p> <ul style="list-style-type: none"> Cost multiplier in the regional objective function (MR_PRICE/MTSOBJ) for a traded commodity (R_TSEP).
BI_TRDCSTELC (r,ie,e,p,td)	<ul style="list-style-type: none"> Monetary units. [open]; no default. 	<ul style="list-style-type: none"> Omit if not desired. 	<p>The additional “transaction” cost for bilateral trading of electricity for each time-slice.</p> <ul style="list-style-type: none"> Cost multiplier in the regional objective function (MR_PRICE/MTSOBJ) for traded electricity (R_TSEPE).



Bi-lateral Trade EQ & VAR

Variables & Equations (Indexes)	Nature	Description
MR_BALE1/2 (r,t,elc,td)	Add elc Variable	The balance equation that ensures that the total amount of electricity produced in each time-slice (season/time-of-day) meets or exceeds that demanded in said time-slice. Equation 1 is for daytime constraints ($w = z, 'D'$) and equation 2 is for the nighttime constraints ($w = z, 'N'$). The time-sliced bi-lateral electricity trade variable (R_TSEPE) needs to be included, where permitted, with the appropriate sign.
MR_BAS (r,t,elc,z)	Add elc Variable	Ensures that those power plants designated as baseload (bas) operate at the same level in the day and night, while not exceeding a percentage of the highest nighttime electricity demand (according to BASELOAD). The time-sliced bi-lateral electricity trade variable (R_TSEPE) needs to be included, where permitted, with the appropriate sign.
MR_BITRD (r,e,r,t,e,p)	New	Matches up the bi-lateral trade of a commodity between two regions. Note that the name of the commodity may be different between the two regions, if desired, but the same supply step (p) must be used.
MR_BITRDE (r,elc,r,t,elc,td)	New	Matches up the bi-lateral trade of electricity between two regions during a particular time-slice. Note that the name of the commodity may be different between the two regions, if desired, but the same supply step (p) must be used.



Bi-lateral Trade EQ & VAR (Cont.)

MR_EPK (t,elc,z)	Add elc Variable	The electricity peaking constraint ensures that there is enough capacity in place to meet the highest average electricity demand during the day of any season + estimated level above that for the actual peak (moment of highest electric demand) + a reserve margin of excess capacity (ERESERV includes both), to ensure that if some plants are unavailable said demand for electricity can still be met. The time-sliced bi-lateral electricity trade variable (R_TSEPE) needs to be included, where permitted, with the appropriate sign.
MR_PRICE (r)	Add elc Variable	The MARKAL clairvoyant total discounted system cost for each region, summed to the objective function. The trade cost (BI_TRDCST/ELC) is applied to the regular/time-sliced electricity trade variable (R_TSEP/TSEPE), where desired.
MR_MTSOBJ (r)	Add elc Variable	The SAGE time-stepped minimum annualized system cost for a region, summed to the objection function, and solved successively for each period of the model run. The trade cost (BI_TRDCST/ELC) is applied to the regular/time-sliced electricity trade variable (R_TSEP/TSEPE), where desired.
MR_REGEL C (r,t,ie,elc,p)	New	Balance equation tying of the time-sliced electricity trade variables (R_TSEPE) to the regular annual electricity variable (R_TSEP).



ANSWER Support for Trade - Input

The screenshot shows the ANSWER-MARKAL Energy Modelling software interface. The main window is titled "newMultiUtopDemoRmtest - ANSWER-MARKAL Energy Modelling". The "Trade" tab is selected in the top menu. Below the menu, there are several data tables and controls for configuring trade parameters.

Subset Items: *All Bilateral and Global Trade Parameters

Region	Description	Status
_LIBRARY	Bilateral and Global Trade	
AAA	Bilateral and Global Trade	
DEMO	Bilateral and Global Trade	
UTOPIA	Bilateral and Global Trade	

Subset Parameters: *0 Bi-lateral and Global Trade

Scenario	Parameter	Region	Commodity	Bound	1990	2000	2010	2020
Add BASE	TRD_BND(ENT)imp	DEMO	DSL	UP	10.0000	10.0000	10.0000	10.0000

Scenario	Parameter	Region	Region2	Technology	Commodity	TimeSlice	Technology2	Commodity2	Value
BASE	BI_TRD(ENT)	UTOPIA	DEMO	EXPDSL1	DSL	-	IMPDSL1	GSL	1
BASE	BI_TRDCSTELC	DEMO	-	EXPDL1	-	I-D	-	-	0.0010
BASE	G_TRADE(ENT)	DEMO	-	-	BIT	-	-	-	777

Database: C:\ANSWER\5\answer_databases\ETP\ENV_ENT\newMultiUtopDemoRmtest.mdb | Library Database:



ANSWER Support for Trade - Run

The screenshot shows the "Model Variant Specification" dialog box. It is used to specify the model variant by selecting a primary variant and adding specific options to it.

Primary Variant: MARKAL

Additions to Primary Variant:

- (None) Damage LP Damage NLP
- (None) Elastic Demand - Income
- (None) Endogenous Technology Learning
- (None) Multi-Region
- (None) SAGE (Time-stepped solve)
- (None) Stochastic Stochastic - Risk
- (None) Goal Programming

Optimizer: LP

Model Variant Description: MARKAL + MultiRegion

Buttons: OK, Cancel

The screenshot shows the "Select Regions To Appear in GAMS DD/DD5" dialog box. It allows the user to select which regions should be included in the GAMS model.

_LIBRARY

AAA

DEMO

UTOPIA

Buttons: Select All, Deselect All, OK, Cancel



ANSWER Support for Trade - Results

DUTEST - ANSWER-MARKAL Energy Modelling

File Edit View Run Tools Functions Help

Results Regions: Items: All Cases: All

Global Energy Material Demand Emission Technology Constraint Tax/Subsidy Stochastic Parameter Trade

Subset Items: *All Bilateral and Global Trade Parameters

Region	Description	Status
DEMO	Bilateral and Global Trade	
UTOPIA	Bilateral and Global Trade	

Subset Parameters: * Bi-lateral and Global Trade TS data

Case	Parameter	Region	Region2	Technology	Energy	TimeSlice	Technology2	Energy2	1990	2000	2010	2020
DUTEST	MR_BITRD[ELC].M	DEMO	UTOPIA	EXPELC1	ELC	W-D	IMPELC1	ELC	-2.16	-2.28	-8.45	-7.45
BITRDCCA	MR_BITRD[ELC].M	DEMO	UTOPIA	EXPELC1	ELC	W-N	IMPELC1	ELC	5.25	3.22	1.98	1.22
DUTEST	MR_BITRD[ELC].M	DEMO	UTOPIA	EXPELC1	ELC	W-N	IMPELC1	ELC	-1.87	-2.16	-7.62	-6.91
BITRDCCA	MR_BITRD[ENT].M	DEMO	UTOPIA	EXPCOAC	COA	-	IMPHCOC	HCO	-1.03	-0.64	-0.39	-0.24
BITRDCCA	MR_BITRD[ENT].M	UTOPIA	DEMO	EXPODSL1	DSL	-	IMPGLS1	GSL	103.48	63.53	39.00	23.94
BITRDCCA	R_TSEP.L	DEMO	-	EXPCOAC	-	-	-	-	3,000.00	3,000.00	3,000.00	3,000.00
BITRDCCA	R_TSEP.L	DEMO	-	IMPGLS1	-	-	-	-	2,653.45	0.00	0.00	0.00
BITRDCCA	R_TSEP.M	DEMO	-	EXPCOAC	-	-	-	-	-10.55	-8.89	-5.66	-3.59
BITRDCCA	R_TSEP.M	DEMO	-	IMPGLS1	-	-	-	-	0.00	65.99	48.12	33.33
BITRDCCA	R_TSEPELC.L	DEMO	-	EXPELC1	-	I-D	-	-	0.00	2.00	2.00	0.00
DUTEST	R_TSEPELC.L	DEMO	-	EXPELC1	-	I-D	-	-	0.56	0.98	1.26	1.26
BITRDCCA	R_TSEPELC.L	DEMO	-	EXPELC1	-	I-N	-	-	0.00	0.00	0.00	2.00
DUTEST	R_TSEPELC.L	DEMO	-	EXPELC1	-	I-N	-	-	0.00	0.14	0.00	0.00
DUTEST	R_TSEPELC.L	DEMO	-	EXPELC1	-	S-N	-	-	0.24	0.98	1.79	1.79
DUTEST	R_TSEPELC.L	DEMO	-	EXPELC1	-	W-D	-	-	2.66	4.06	6.00	6.00
BITRDCCA	R_TSEPELC.L	DEMO	-	EXPELC1	-	W-N	-	-	2.00	0.00	0.00	0.00
DUTEST	R_TSEPELC.L	DEMO	-	EXPELC1	-	W-N	-	-	0.42	0.70	0.96	0.96
BITRDCCA	R_TSEPELC.M	DEMO	-	EXPELC1	-	I-D	-	-	2.91	0.00	0.00	1.31
BITRDCCA	R_TSEPELC.M	DEMO	-	EXPELC1	-	I-N	-	-	0.00	0.00	0.00	0.00
DUTEST	R_TSEPELC.M	DEMO	-	EXPELC1	-	I-N	-	-	0.31	0.00	2.13	1.26
BITRDCCA	R_TSEPELC.M	DEMO	-	EXPELC1	-	S-D	-	-	246.23	140.22	79.48	43.94

Database: C:\ANSWER\5\answer_databases\DUTEST.mdb Library Database:



VEDA-SAGE Support for Trade - Input

VEDA_SAGE : SAGE Model

File Module -1 Module -2 Tools Window Help

VEDA_SAGE: Browse/Edit

Trades

Trades Matrix

Commodity: COARCO
Emission Permits: CO2PHT
Associated: TOTCO2

Hard coal [New] [Delete]

		I M P O R T E R S																		
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
E X P O R T E R S	1																			
	2																			
	3		AFR	AUS	CAN	CHI	CSA	EEU	FSU	GLB	IND	JPN	MEA	MEX	ODA	SKO	USA	WEU		
	4		AFR																	
	5		AUS																	
	6		CAN																	
	7		CHI																	
	8		CSA																	
	9		EEU																	
	10		FSU																	
	11		GLB																	
	12		IND																	
	13		JPN																	
	14		MEA																	
	15		MEX																	
	16		ODA																	
	17		SKO																	
	18		USA																	
		WEU																		

Ready | SAGE_0306.MDB | Tuesday, June 17, 2003, 05:24 PM



VEDA-SAGE Support for Trade – Input (Cont.)

The screenshot shows the 'Trades Prmtr Data' dialog box in the VEDA-SAGE software. The commodity is set to 'COAHCO' (Hard coal) and the importer is 'BOUND(BD)OR'. The year is 2000, and the bound is 'UP'. The main part of the dialog is a grid titled 'I M P O R T E R S' showing trade flows between regions. The regions listed are AFR, AUS, CAN, CHI, CSA, EEU, FSU, GLB, IND, JPN, MEA, MEX, ODA, SKO, USA, and WEU. The grid shows trade flows from the commodity's origin to these regions. A value of 200.0 is visible in the cell for region WEU.

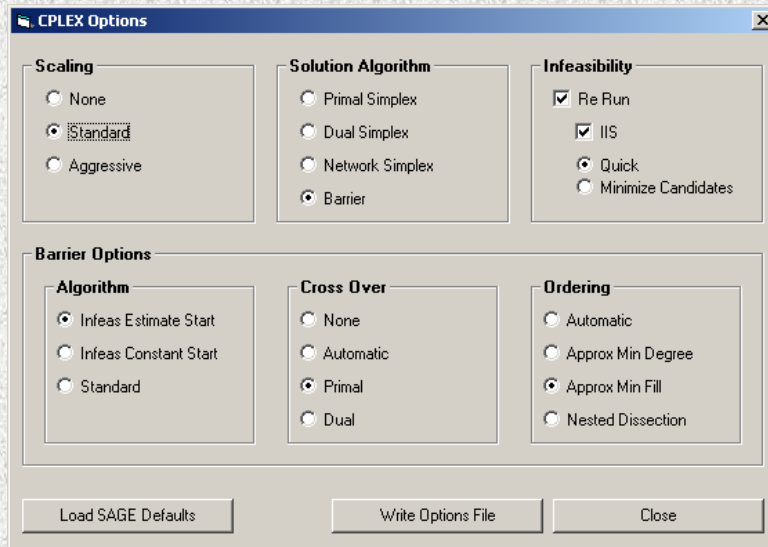


VEDA-SAGE Support for Trade – Run

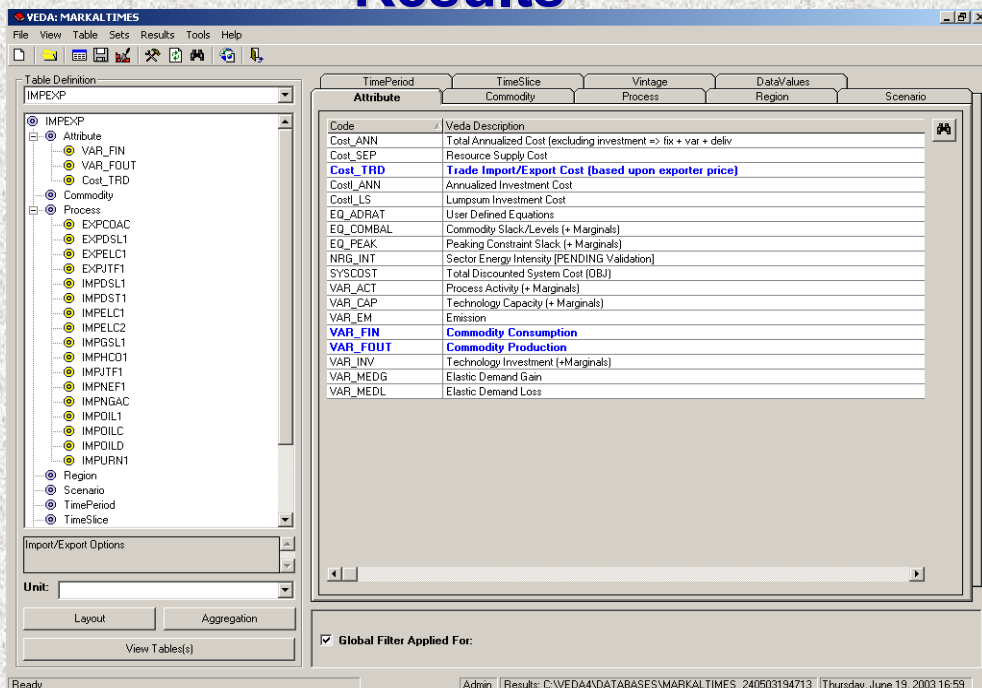
The screenshot shows the 'Solve' dialog box in the VEDA-SAGE software. The scenario is 'BASE'. The regions selected are USA and WEU. The model variant is 'SAGE0'. The solver is set to 'CPLEX'. The 'Elastic Demands' checkbox is unchecked. The 'Foresight' option is set to 'Clairvoyant'. The 'Market Share' checkbox is unchecked. The 'GAMS' source directory is 'GAMS_SRC SAGE'. The 'Ending Year' is 2020. The 'Solve' button is highlighted.



VEDA-SAGE Support for Trade – Run (Cont.)



VEDA-SAGE Support for Trade – Results



VEDA-SAGE Support for Trade – Results (Cont.)

Region	Attribute	Commodity	Process	TimePeriod							
				1990		2000		2010		2020	
				PV	DV	PV	DV	PV	DV	PV	DV
DEMO	Cost_TRD	ELC	EXPEL1	-26.59	0.00	-29.99	0.00	-99.53	0.00	-90.84	0.00
			IMPDSL1	26,534.50	0.00	--	--	--	--	--	--
	VAR_FIN	COA	EXPCOAC	3,000.00	-0.12	3,000.00	-0.30	3,000.00	-0.10	3,000.00	-0.70
			EXPEL1	3.98	0.00	2.80	0.00	7.82	0.00	9.27	0.00
	JTF	EXPJTF1		0.00	-2.16	0.00	-3.50	0.00	0.73	0.00	1.34
			CO2	-65,100.00	0.00	-65,100.00	0.00	-65,100.00	0.00	-65,100.00	0.00
	VAR_FOUT	CO2	EXPCOAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			EXPJTF1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			IMPDST1	74,687.86	0.00	0.00	0.00	38,677.30	0.00	0.00	0.00
			IMPDSL1	46,435.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			IMPJTF1	0.00	0.00	0.00	0.00	0.00	0.00	13,664.08	0.00
			IMPNEF1	20,801.20	0.00	0.00	0.00	17,268.81	0.00	13,827.55	0.00
			IMPNGAC	24,500.00	0.00	8,333.33	0.00	4,166.67	0.00	0.00	0.00
			IMPOILC	296,257.50	0.00	414,425.00	0.00	347,745.11	0.00	293,869.29	0.00
			IMPOILD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			DST	IMPDST1	4,267.88	0.00	0.00	0.16	2,210.13	0.00	0.00
	ELC	IMPDL1		5.00	-7.09	5.00	-10.58	5.00	-11.76	5.00	-9.56
			IMPDL2	10.00	-10.86	10.00	-14.24	10.00	-14.25	10.00	-11.42
	GSL	IMPDSL1		2,653.45	0.00	0.00	5.01	0.00	5.58	0.00	3.82
			IMPJTF1	0.00	3.08	0.00	4.21	0.00	0.15	780.80	0.00
INGA	IMPNGAC		1,960.00	-0.77	666.67	0.13	333.33	0.07	0.00	0.06	
		IMPOILC	16,929.00	0.00	23,681.43	0.00	19,871.15	0.00	16,792.53	0.00	
OIL	IMPOILD		0.00	97.82	0.00	97.02	0.00	96.05	0.00	94.10	
		IMPDSL1	-26,534.50	0.00	--	--	--	--	--	--	
LUTOPIA	Cost_TRD	ELC	EXPEL1	26.59	0.00	29.99	0.00	99.53	0.00	90.84	0.00
			IMPDSL1	2,653.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VAR_FOUT	CO2	EXPJTF1		202.18	0.00	5.34	0.00	9.49	0.00	9.87	0.00



Recent Adjustments for Bi-lateral and Global Trade

- Add TRD_BND to allow IMP/EXP of R_GTRD global trade variables to be constrained
- Make TRD_COST time-dependent
- Add bi-lateral and global trade and cost information to reports (T02/T25/T27/VEDA)
- QC that 'P'rice steps line upon on bi-lateral trade specifications
- MED reference files named <region>.EDD for multi-region runs
- Overall scaling of the OBJ via GobjZScal



SAGE Components

- Multi-region, time-stepped, annualized cost objective function model variant; with inter-period market share and technology learning algorithms
- VEDA-SAGE
- VEDA4



SAGE: Activation, Data and Results

- Control switches
- MKTSHR data & algorithm
- SETL data
- LOG files and other output



SAGE: Run Control Switches

MKTSHR	<ul style="list-style-type: none"> • INV • INVPCT • ACT 	<ul style="list-style-type: none"> • Activate the market share algorithm based upon the marginal cost of the investment variable. • Activate the market share algorithm based upon the marginal cost of the investment variable as a share of current investment cost in the period. • Activate the market share algorithm based upon the activity of the technology (for demand devices only at this time).
MKTSHRLOG	<ul style="list-style-type: none"> • MIN • ALL 	<ul style="list-style-type: none"> • Write the minimal trace of the decisions made as part of the market share algorithm to the MKTSHR.LOG file. • Write the full trace of all the decisions made as part of the market share algorithm to the MKTSHR.LOG file.
SAGE	<ul style="list-style-type: none"> • YES • any other value 	<ul style="list-style-type: none"> • Activate the time-stepped technique for successively optimizing of the energy system period by period, rather than clairvoyantly over the entire modeling horizon as is done with MARKAL. • Solve in a single step with perfect foresight over the entire modeling horizon.
SETL	<ul style="list-style-type: none"> • YES • any other value 	<ul style="list-style-type: none"> • Activate the endogenous technology-learning algorithm that derives the current investment cost of a technology as a function of cumulative capacity in place up to and including the previous period. • Do not activate the technology learning algorithm.



SAGE: Market Share Data - Sets

Set ID/ Index	Alias/ Linked	Description
ADRATIO (a/m)	mkt_id	<p>The list of modeler defined constraints, or ADRATIOS, as well as the SAGE market share subset group (mkt_id) that may replace said ADRATIO according to the AMSWTC control switch.</p> <ul style="list-style-type: none"> • For each ADRATIO (not involved in an active MKTSHR group), an MR_ARATx equation is created (as long as a RAT_RHS entry is provided).
ANSWTC (ADRATIO, AMS) (a/m)	Adratio/ mkt_id	<p>Indication of how to treat individual ADRATIOS with respect to the market share groups, according to which of the three values for the ADRATIO/MKTSHR switch is activated as described here.</p> <ul style="list-style-type: none"> • AMS = 'A', always generate the ADRATIO • AMS = 'B', generate as a ADRATIO or MKT_ID depending upon whether MKTSHR is active. [Default, if MKTSHR is active suppress generation of the MKT_ID=ADRATIO ADRATIOS.] • AMS = 'X', ignore the ADRAIO is MKTSHR is active, regardless of whether or not a corresponding MKT_ID exists.
MKT_GRP (mkt_id,tch)		<p>The mapping of the individual technologies subject to the market share algorithm (when MKTSHR activated, see section 4.4) indicating the group to which the technology is assigned.</p>
MKT_ID		<p>The set of user provided names for the groups of technologies to be involved in the market share algorithm (when MKTSHR activated, see section 4.4). MKT_IDs often correspond directly to the ADRATIOS that they substitute for when the market share algorithm is activated.</p>



SAGE: Market Share Data – Parameters

Input Parameter (Indexes)	Units/ Range & Defaults	Instance (Required/Omit/ Special Conditions)	Description
MKT_CE (m)	<ul style="list-style-type: none"> Either percent (if MKTSHR = INVPCT) or monetary units (if INV) or activity units (if ACT). [depends on MKTSHR type], default = 2. 	<ul style="list-style-type: none"> Required if MKTSHR is activated (see section 4.4) for each MKT_ID group, unless default will do. Must be provided for each group if MKTSHR is not INVPCT. 	<p>The “close enough” criteria qualifying a technology to get a share of a market based on how close to being competitive the technology is when it does not make it into the preliminary solve for a period.</p> <ul style="list-style-type: none"> Involved in each market share group evaluation to determine the candidates to be included in the re-assignment of the shares for the competing technologies.
MKT_GAMA (m)	<ul style="list-style-type: none"> Scalar. [1-5]; default = 2. 	<ul style="list-style-type: none"> Provided if MKTSHR is activated (see section 4.4) for each MKT_ID group, unless default will do. 	<p>The degree of optimization to be applied when determining the share for qualifying candidates in a market share group.</p> <ul style="list-style-type: none"> Involved in each market share group evaluation to determine how much of a share each of the candidates is to receive.



SAGE: Market Share Data – Parameters (Cont.)

MKT_LO (m)	<ul style="list-style-type: none"> Either percent (if MKTSHR = INVPCT) or monetary units (if INV) or activity units (if ACT). [depends on MKTSHR type], default = .00001. 	<ul style="list-style-type: none"> Provided if MKTSHR is activated (see section 4.4) for each MKT_ID group, unless default will do. 	<p>Tiny lower bound applied to the investment variable (R_INV) if MKTSHR is INV or INVPCT, or capacity (R_CAP) if MKTSHR is ACT.</p> <ul style="list-style-type: none"> Applied to each MKT_GRP technology to force a marginal value on each candidate.
MKT_PREF (mkt_id,tch)	<ul style="list-style-type: none"> Scalar. [.001 - 5]; default = 1. 	<ul style="list-style-type: none"> Provided if MKTSHR is activated (see section 4.4) for each MKT_ID group, if a weighted preference is desired unless default will do. 	<p>preference or weighting factor applied to an individual technology when determining its share as part of the market share algorithm.</p> <ul style="list-style-type: none"> Involved in each market share group when determining how to split the reallocation group and how much of a share the candidate is to receive.
MKT_REAL (m)	<ul style="list-style-type: none"> Scalar. [.001 - 1]; default = 2. 	<ul style="list-style-type: none"> Provide if MKTSHR is activated (see section 4.4) for each MKT_ID group, unless default will do. 	<p>The size of the market to subject to the reallocation algorithm.</p> <ul style="list-style-type: none"> Involved in each market share group when determining how big the market to be reallocated is to be.
MKT_RARC (m)	<ul style="list-style-type: none"> Scalar. [.000001 - 1]; default = .1. 	<ul style="list-style-type: none"> Provided if MKTSHR is activated (see section 4.4) for each MKT_ID group, unless default will do. 	<p>The size of the market to subject to the 2nd reallocation pass if one of the reallocated shares exceeds the smallest basic technology that had penetrated during the initial solve.</p> <ul style="list-style-type: none"> Involved in each market share group 2nd reallocation algorithm.



SAGE: MKTSHR Algorithm

- Identify Market Candidates
- Initial Solve
- Determine Market Qualifiers
- Evaluating the Size of Reallocation Group
- Market Share Calculation
- Determine Reallocation Value
- Perform Integrity Test
- Assignment of Lower Limit
- Resolving with Reallocated Market Shares



SAGE: MKTSHR LOG – Set Up

```
+++ MKT_GRP Candidates as Provided by User based upon MKTSHR/RAA = INV/2 +++
MarketShare Group/Technology      S_TRT_GMS/TRTGCA005
MarketShare Group/Technology      S_TRT_GMS/TRTGCA010
MarketShare Group/Technology      S_TRT_GMS/TRTGCB005
Etc..

+++ Checking ADRATIOs for MKT_GRP technologies involved +++
* NOTE - MKT_ID == ADRATIO, so ADRATIO suppressed: S_TRT_GCA
* NOTE - MKT_ID == ADRATIO, so ADRATIO suppressed: S_TRT_GCB
* NOTE - MKT_ID == ADRATIO, so ADRATIO suppressed: S_TRT_GCC

+++ Values for BIAS +++
BIAS                               :          1.00000

+++ Checking for TCH FX/UP Bound = 0 for MKT_ID +++ (But MKTSHRLOG = MIN so not listed)

+++ GAMMA/REAL/RAP Values for MKT_ID Groups +++
Commodity                          S_TRT_GMS          : 0.25000/0.20000/0.80000

+++ MKT_CAND Qualifying Candidates and CE/PREF Values for MKT_ID Groups +++
Commodity/Technology               S_TRT_GMS/TRTGCA005 : 300.00000/      1.00000
Commodity/Technology               S_TRT_GMS/TRTGCA010 : 300.00000/      1.00000
Commodity/Technology               S_TRT_GMS/TRTGCB005 : 300.00000/      1.00000
Etc..
```



SAGE: MKTSHR LOG – 1st Pass

+++ Checking for Candidates that dont Qualify - 2010 +++

- Note - MKT_ID/TCH/TS marginal <= 0 so in MKT_SZ but not MKT_QUAL:
S_TRT_GMS/TRTGCA005/2010 Value: 0.00000

=== Calculated SM/SZ/(Total RC or Ratio) Values for MKT_ID Groups ===
MKT_ID S_TRT_GMS : 967.44652/ 967.44656/ 2.37655

=== Solution LVL/MRG/UP(Orig) Value for MKT_0 Candidates for Orig Groups ===
Technology TRTGCA005 : 967.44652/ 0.00000/ +INF

=== Sol LVL/MRG/IRAT(for INVPCT) and Calc SHR/ALLO/VAL Values for Orig Groups ===
Technology TRTGCA010 : 0.00000/ 0.35548/ 0.00000/
0.54494/ 0.20000/ 105.44061
Technology TRTGCB005 : 0.00000/ 60.71361/ 0.00000/
0.15074/ 0.20000/ 29.16684

etc...



SAGE: MKTSHR LOG – Reallocation

+++ Reallocating MKTSHRs owing to some MKT_VAL > MKT_SM +++

=== Solution LVL/MRG/UP(New) Value for MKT_0 Candidates for New Groups ===
Technology TRTGCA005 : 967.44652/ 0.00000/ 773.95724

=== Sol LVL/MRG/IRAT(for INVPCT) and Calc SHR/ALLO/VAL Values for New Groups ===
Technology TRTGCA010 : 0.00000/ 0.35548/ 0.00000/
0.54494/ 1.00000/ 105.44061
Technology TRTGCB005 : 0.00000/ 60.71361/ 0.00000/
0.15074/ 1.00000/ 29.16684

Etc..

=== Final LVL/MRG/BD Values after RESOLVE for Candidates (MKT_0 then MKT_QUAL) ===
Technology TRTGCA005 : 773.95724/ -0.40568/ 773.95724
Technology TRTGCA010 : 107.34412/ 0.00000/ 105.44061
Technology TRTGCB005 : 29.16684/ 60.46273/ 29.16684
Technology TRTGCB010 : 29.08315/ 61.21619/ 29.08315
Technology TRTGCC010 : 29.79871/ 55.45574/ 29.79871



SAGE: ETL Data

Input Sets & Parameters (Indexes)	Units/ Range & Defaults	Instance (Required/Omit/ Special Conditions)	Description
CCAP0 (tch)	<ul style="list-style-type: none"> Capacity units. [any], none. 	<ul style="list-style-type: none"> Required if SETL activated (see section 4.4) for each technology to be subjected to endogenous learning that already has some installed capacity base. 	<ul style="list-style-type: none"> Initial cumulative capacity when the learning algorithm starts up. The existing cumulative installed capacity for a learning technology.
LSPILL_R (r,tch,r,teg,t)	<ul style="list-style-type: none"> Fraction. [.01 - 1], none. 	<ul style="list-style-type: none"> Provided if SETL activated (see section 4.4) for learning technologies that have learning components. 	<ul style="list-style-type: none"> The amount of learning that “spills” from one technology to another to contribute to the latter’s learning rate. There is also a regional form of LSPILL_R that handles “spill” between regions and technologies. Results in a portion of the cumulative investment of a learning component to be taken into consideration when determining the current costs for a “dependent” learning technology.
PRAT (tch)	<ul style="list-style-type: none"> Ratio. [.01 - 1], none. 	<ul style="list-style-type: none"> Required if SETL activated (see section 4.4) for each technology to be subjected to endogenous learning. 	<ul style="list-style-type: none"> Progress ratio, or the driver for determining the amount by which the investment cost changes for every doubling of capacity. Used to determine the current investment costs based upon the anticipated progress as a function of the cumulative capacity installed.



SAGE: ETL Data

SC0 (tch)	<ul style="list-style-type: none"> Monetary units. [any], none. 	<ul style="list-style-type: none"> Required if SETL activated (see section 4.4) for each technology to be subjected to endogenous learning. 	<ul style="list-style-type: none"> Cost of the initial capacity when the learning algorithm starts up. Used to determine the current investment costs based upon this initial cost and the subsequent amount of cumulative capacity installed.
TEG (tch)			Set indicating those technologies subject to the endogenous technology learning algorithm when SETL active.



SAGE: ETL Formulation

- Determine if total installed capacity exceeds CCAP0
- Calculate new specific investment cost, including consideration of learning “spill”

$$SC_{r,i} = SC0_{r,i} * [CC_{r,j} + \text{SUM}((r',t), \text{lspill}_{r',t,r,j} * CC_{r',t})]^{-\frac{\ln(\text{PRATj})}{\ln(2)}}$$

- Adjust TEG technologies' INVCOST for next period



SAGE: VEDA-SAGE

{DEMO}



SAGE: VEDA4

{DEMO}



Major Developments: SAGE Possible Future Activities

- Endogenous calculation of learning rate as cumulative capacity builds
- Link to an economic module
- Some form of expectation or limited (flexible) look ahead
- Investigation of other approaches for the MKTSHR algorithm
- Miscellaneous
 - STK may not be specified with SAGE (no checks done)
 - Cumulative =N= rows should be suppressed



Major Developments: ETP

- Enhance ANSWER multi-region support
(_LIBRARY & ADRATIO “macros”)
- Emissions accounting tied to commodities
(ENV_ENT)
- Demand device vintaging
(I/REFF)



ETP: Enhanced ANSWER Multi-region Support

{DEMO}



ETP: Emissions Tied to Commodities

- New ENV_ENT(env,ent/mat,year) emissions table
- Keys on commodity flows into (+releases to emission “balance” equation (MR_TENV) and out of (just materials, -reduction of emissions in “balance” equation) technologies and import/exports
- Technology performance characteristics (e.g., efficiency, output splits) taken into consideration, permitting actual emission rates to be entered



ETP: Emissions Tied to Commodities (Cont.)

- May greatly reduce data input (as not technology-based), but may require “shadow” (material) commodities
- Proper accounting framework must be laid out with care
- Debugging “dump” of the net emission contribution from each technology/resource involved



ETP: Emissions Tied to Commodities (ENV_ENT Energy Rules)

Technology Type	Input Parameters	Associated ENV Parameter	Emission (or credit) release owing to
CON	INP(ENT)c	ENV_ACT	Consumption of energy in the current period
	INP(ENC)_TIDc	ENV_INV	Consumption of energy at investment time
DMD	MA(ENT)	ENV_ACT	Consumption of energy in the current period
	MA(ENC)_TID	ENV_INV	Consumption of energy at investment time
PRC	INP(ENT)p	ENV_ACT	Consumption of energy in the current period
	LED(ENT)	ENV_ACT	Consumption of energy in the previous period
	INP(ENC)_TIDp	ENV_INV	Consumption of energy at investment time
SRCENCP	INP(ENT)r	ENV_SEP	Consumption of energy as part of a resource activity
	INP(ENT)x	- ENV_SEP	Export of an energy carrier (emission credit)



ETP: Emissions Tied to Commodities (ENV_ENT Material Rules)

Technology Type	Input Parameters [emission production]	Output Parameters [emission reduction]	Associated ENV Parameter	Emission release or reduction/capture owing to
CON	INP(MAT)c	OUT(MAT)c	ENV_ACT	Consumption/release of material in the current period
	INP(MAT)_TIDc	OUT(MAT)_TIDc	ENV_INV	Consumption/release of material at investment/dismantling time
DMD	MA(MAT)	MO(MAT)	ENV_ACT	Consumption/release of material in the current period
	MA(MAT)_TID	MO(MAT)_TID	ENV_INV	Consumption/release of material at investment/dismantling time
PRC	INP(MAT)p	OUT(MAT)p	ENV_ACT	Consumption/release of material in the current period
	LED(MAT)	LAG(MAT)	ENV_ACT	Consumption/release of material in the previous/next period
	INP(MAT)_TIDp	OUT(MAT)_TIDp	ENV_INV	Consumption/release of material at investment/dismantling time
SRCENCP	INP(MAT)r	OUT(MAT)r	ENV_SEP	Consumption of material as part of a resource activity
			ENV_SEP	Production of material, including imports
	INP(MAT)x	- ENV_SEP	Export of material	



ETP: Emissions Tied to Commodities (ENV_ENT “Net” Coefficient Dump)

```
"-SEP-", "XXX", "UTOPIA", "EXP", "DSL", "1", -1.0000, -1.0000, -1.0000, -1.0000
"-ACT-", "XXX", "UTOPIA", "SRE", 1.0000, 1.0000, 1.0000, 1.0000
"-CAP-", "XXX", "UTOPIA", "RHO", 1.4286, 1.4286, 1.4286, 1.4286
"-CAP-", "XXX", "UTOPIA", "TXD", 4.3290, 4.3290, 4.3290, 4.3290
"-CAP-", "XXX", "UTOPIA", "TXG", 2.1645, 2.1645, 2.1645, 2.1645
"-INVD-", "XXX", "UTOPIA", "TXX", "1990", 3.5714, 1.7857, 0.0000, 0.0000
"-INVD-", "XXX", "UTOPIA", "TXX", "2000", 0.0000, 3.5714, 1.7857, 0.0000
"-INVD-", "XXX", "UTOPIA", "TXX", "2010", 0.0000, 0.0000, 3.0488, 1.5244
"-INVD-", "XXX", "UTOPIA", "TXX", "2020", 0.0000, 0.0000, 0.0000, 2.9762
"-TEZY-", "XXX", "UTOPIA", "E01", "I", "D", 6.2500, 6.2500, 6.2500, 6.2500
"-TEZY-", "XXX", "UTOPIA", "E01", "S", "D", 6.2500, 6.2500, 6.2500, 6.2500
"-TEZY-", "XXX", "UTOPIA", "E01", "W", "D", 6.2500, 6.2500, 6.2500, 6.2500
"-TEZY-", "XXX", "UTOPIA", "E70", "I", "D", 3.4000, 3.4000, 3.4000, 3.4000
... etc ...
"-TEZY-", "XXX", "UTOPIA", "E70", "W", "N", 3.4000, 3.4000, 3.4000, 3.4000
... etc ...
```



ETP: Demand Device Vintaging

- **PURPOSE:** Permit the efficiency of demand devices to change over time (so that separate “cloned” vintage versions are not necessary)
- **DATA:** New EFF_I (for investments) and EFF_R (for RESIDs) parameters in place of just EFF
- **IMPLICATIONS:** All instances (matrix (including DELIV) and reports) of CAP adjusted to work with INV (applying EFF_I from the year of investment) and RESIDV (applying EFF_R in the current year) when EFF_I provided



Considerations for the Future: Incorporating Advanced Features (towards TIMES or not?)

- Allow TD to be under user control
 - Associated requirement to adjust peak, baseload and storage
- Allow flexible period lengths
- Permit inter-temporal and cross-region ADRATIOs
- Other enhancements worth considering?



Considerations for the Future: Data Handling Systems

- VEDA-SAGE (MARKAL/TIMES)
- ANSWER-ETP
- VEDA4

- ANSWE-TIMES

