Energy Research Institute of the
Russian Academy of Sciences

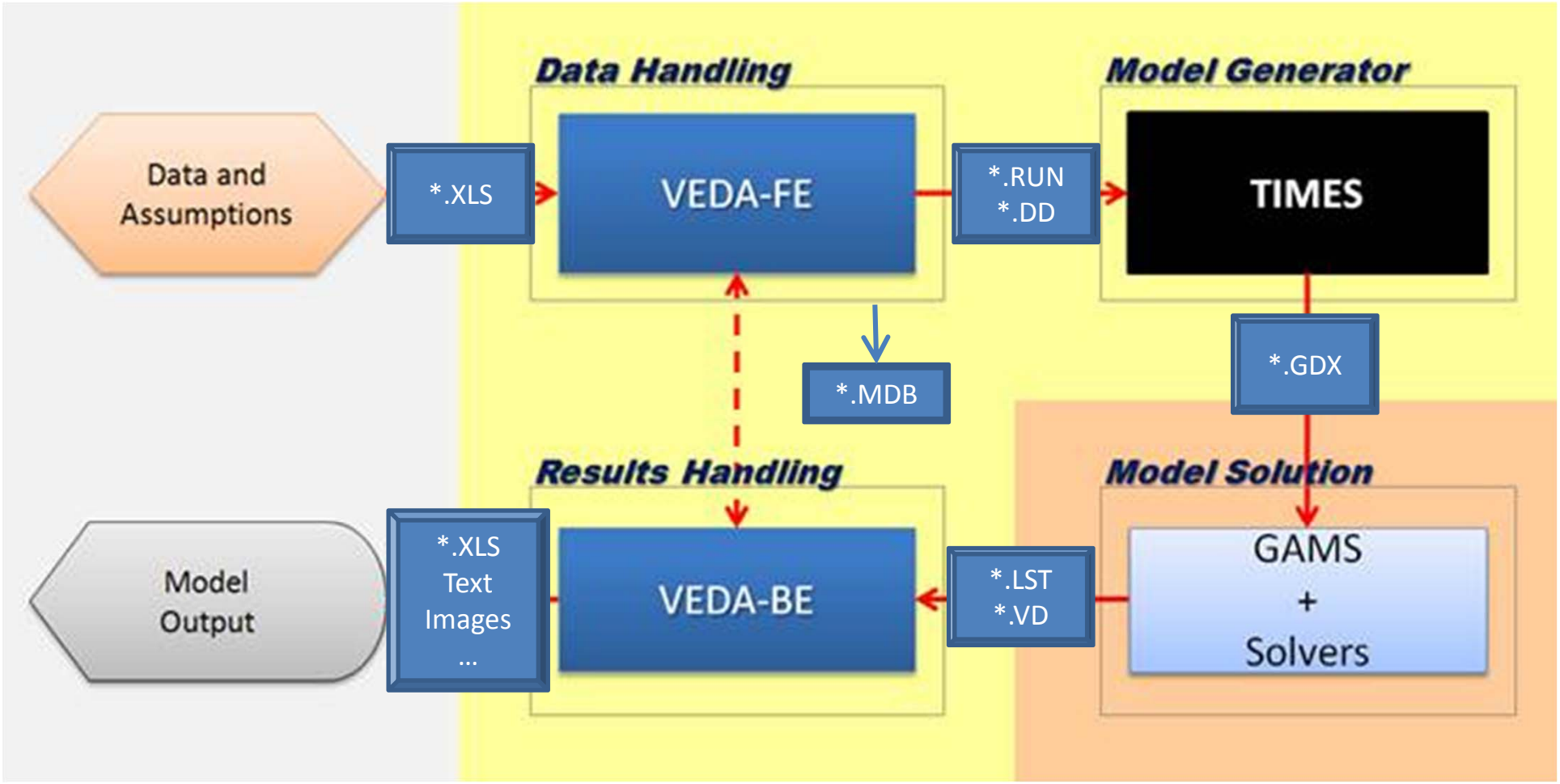
World modelling with TIAM: first experience

1. ETSAP modelling tools
2. TIAM model study
3. Further model usage

Greece, 2011

1. ETSAP modelling tools

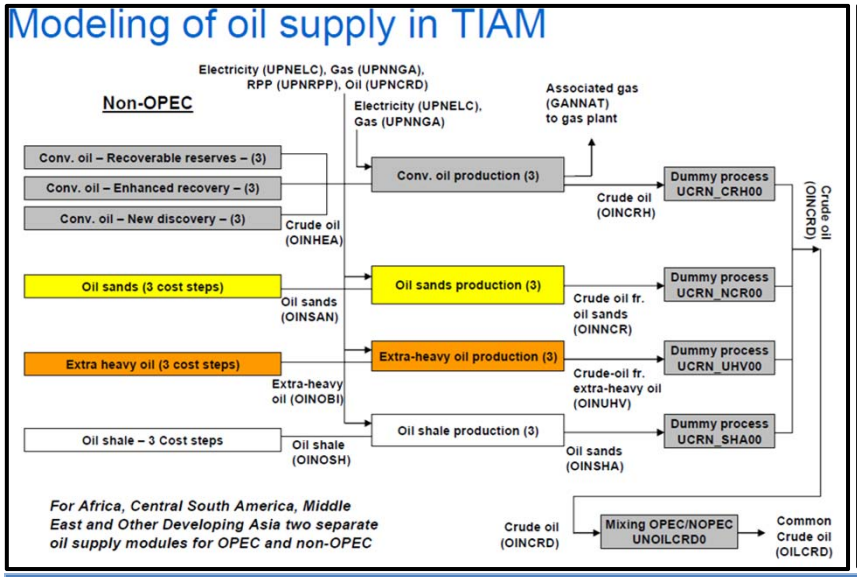
(Energy Technology Systems Analysis Program)

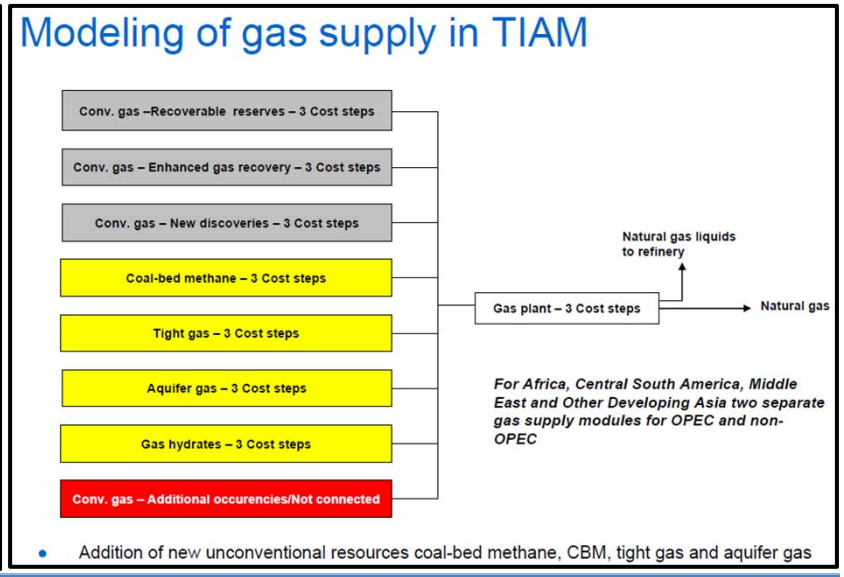


2. TIAM -> input data

Fossil fuels supply

Data is set by region, types and cost steps for oil, gas and coal



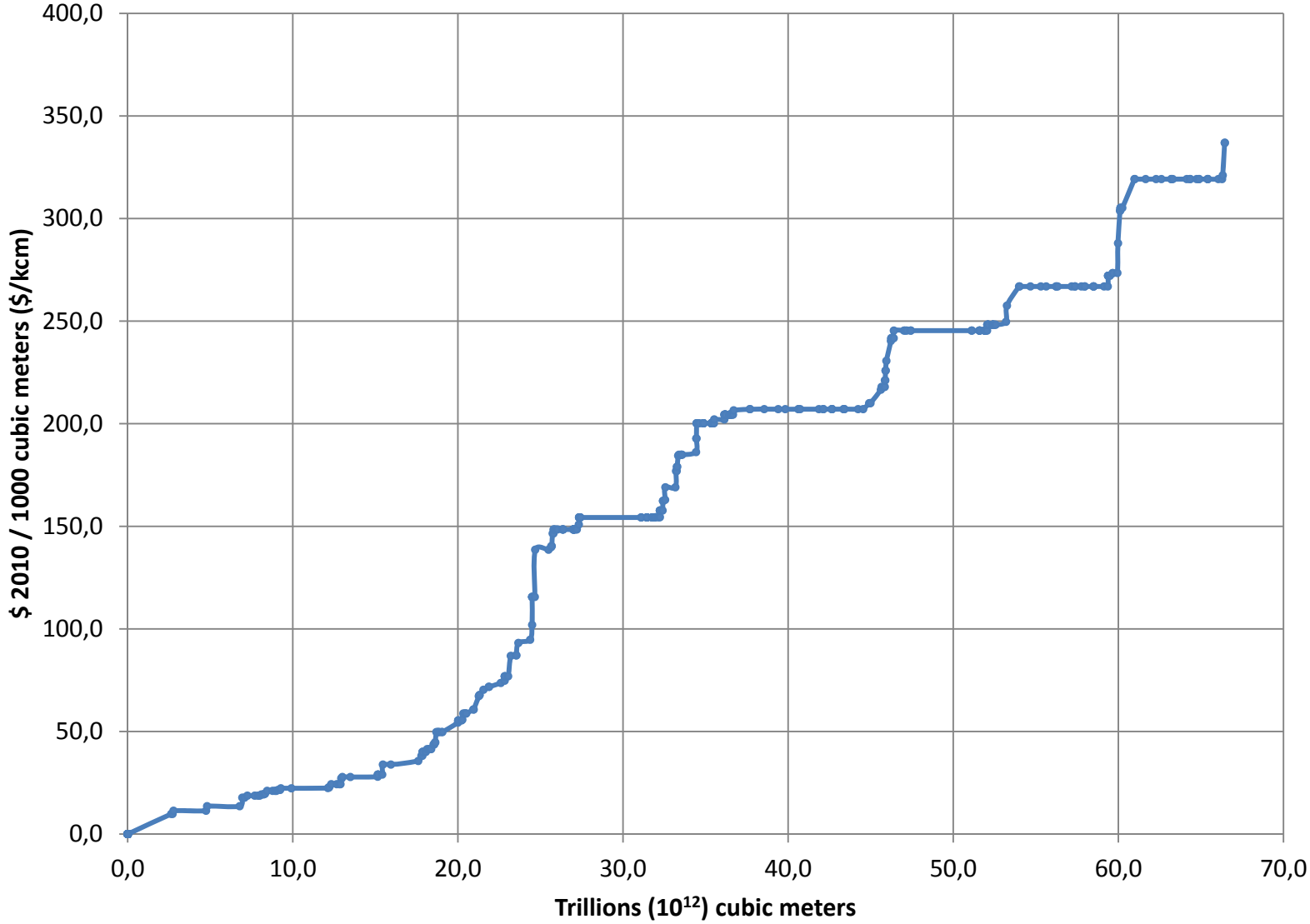


Country	Pset_PN (CommGRP)	Description	Cset_CN	Description	LimType	ACT_BND 2005	COST 2005	ACT_BND 2050	COST 2050	ACT_BND 2100	COST 2100
CAN	MINOINOBI1	Oil sands (in situ - ultra hvy) - Located reserves - Step 1 - Nopec	OINOBI	Oil sands (in situ - ultra hvy) - Nopec		49,329.9	2.1	49,329.9		49,329.9	2.0
CAN	MINOINOBI2	Oil sands (in situ - ultra hvy) - Located reserves - Step 2 - Nopec	OINOBI	Oil sands (in situ - ultra hvy) - Nopec		49,329.9	2.2	49,329.9		49,329.9	2.1
CAN	MINOINOBI3	Oil sands (in situ - ultra hvy) - Located reserves - Step 3 - Nopec	OINOBI	Oil sands (in situ - ultra hvy) - Nopec		24,665.0	2.4	24,665.0		24,665.0	2.3
CAN	MINOINHEA1	Heavy oil (ground) - Located reserves - Step 1 - Nopec	OINHEA	Heavy oil (ground) - Nopec		19,416.5	2.7	19,416.5		19,416.5	2.5
CAN	MINOINHEA3	Heavy oil (ground) - Located reserves - Step 3 - Nopec	OINHEA	Heavy oil (ground) - Nopec		7,766.6	4.3	7,766.6		7,766.6	4.1
CAN	MINOINHEA4	Heavy oil (ground) - Reserves growth - Step 1 - Nopec	OINHEA	Heavy oil (ground) - Nopec		6,462.2	4.5	6,462.2		6,462.2	4.3
…	…	…	…	…		…	…	…		…	…

Source: ETSAP-TIAM some details on model and database

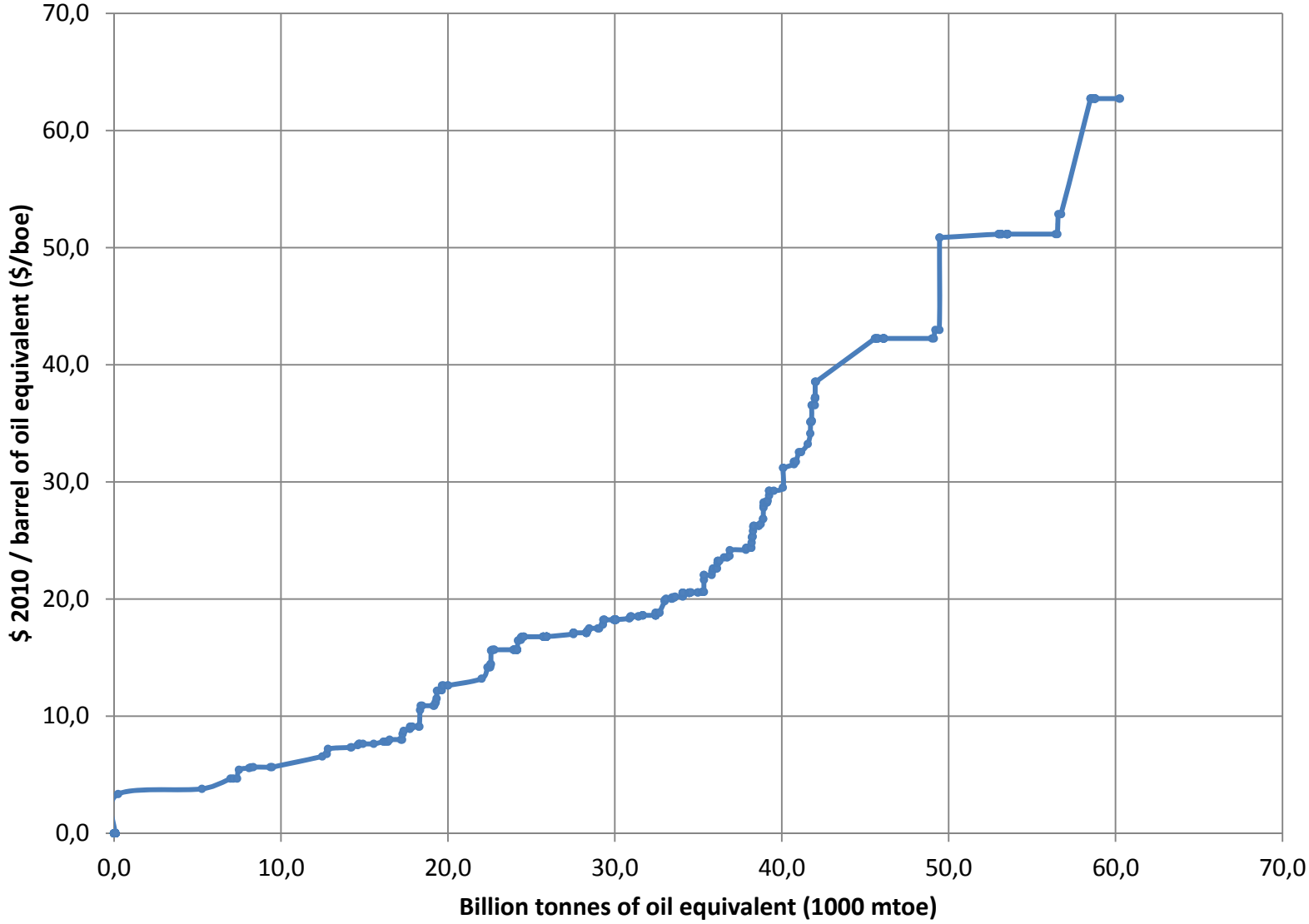
2. TIAM -> input data

World supply curve for gas



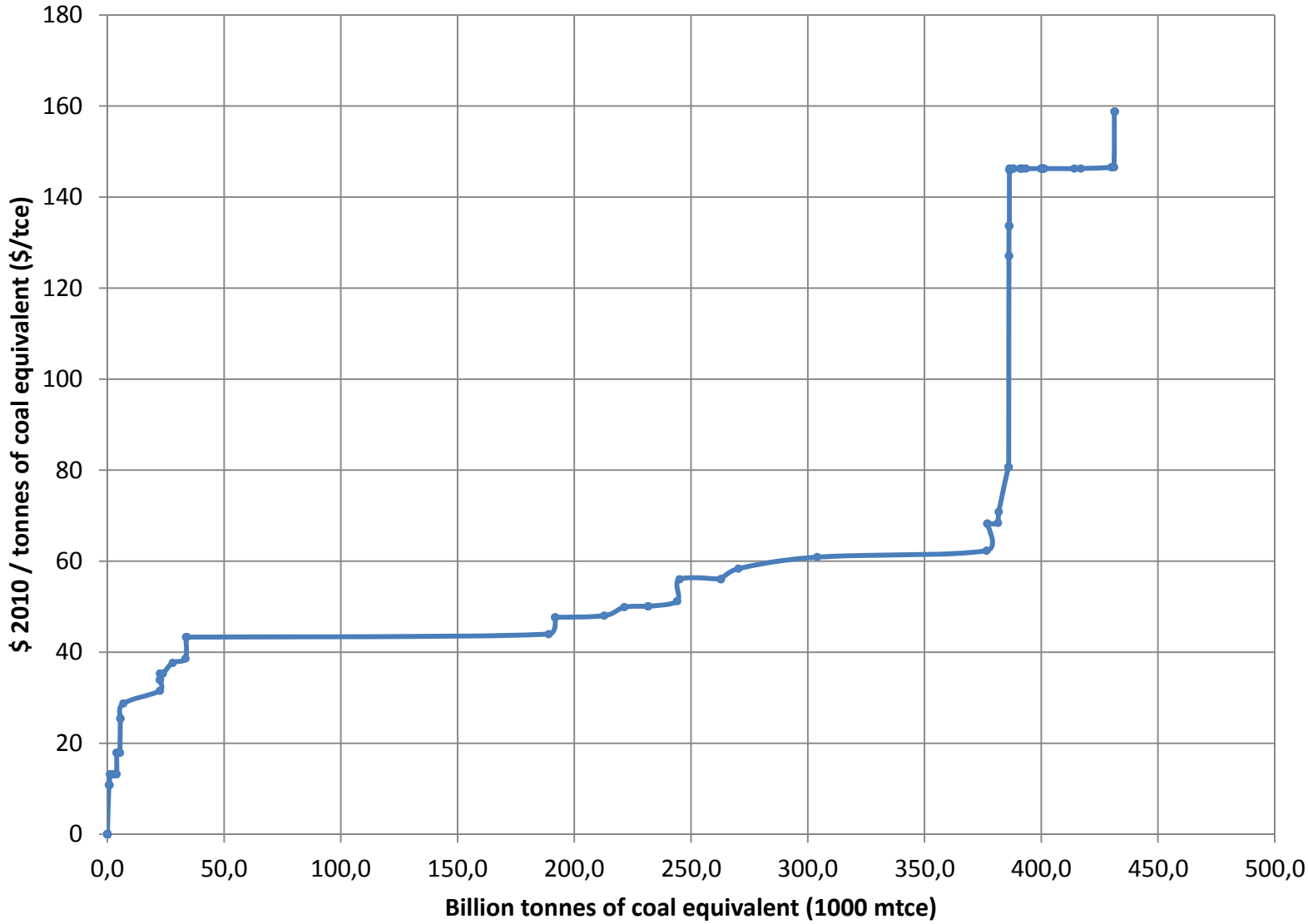
2. TIAM -> input data

World supply curve for oil



2. TIAM -> input data

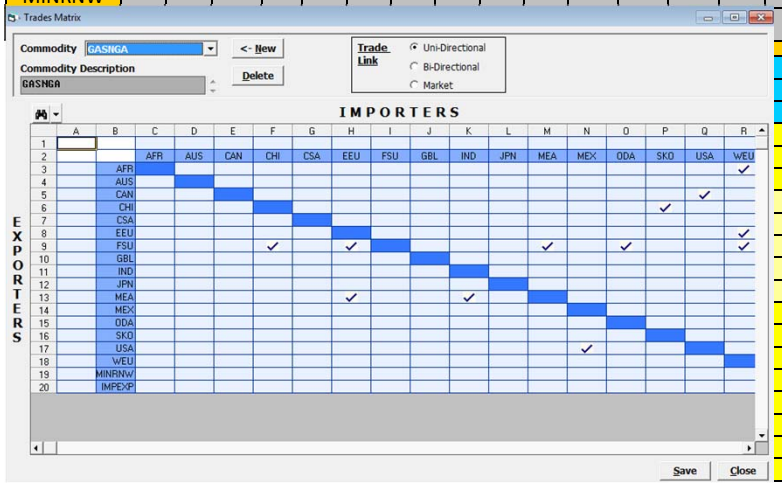
World supply curve for coal



2. TIAM -> input data

Inter-regional connections

GASNGA	AFR	AUS	CAN	CHI	CSA	EEU	FSU	GBL	IND	JPN	MEA	MEX	ODA	SKO	USA	WEU	MINRNW	IMPEXP
AFR																1		
AUS																		
CAN															1			
CHI														1				
CSA																		
EEU																1		
FSU				1		1					1		1			1		
GBL																		
IND																		
JPN																		
MEA						1			1									
MEX																		
ODA																		
SKO																		
USA												1						
WEU																		
MINRNW																		

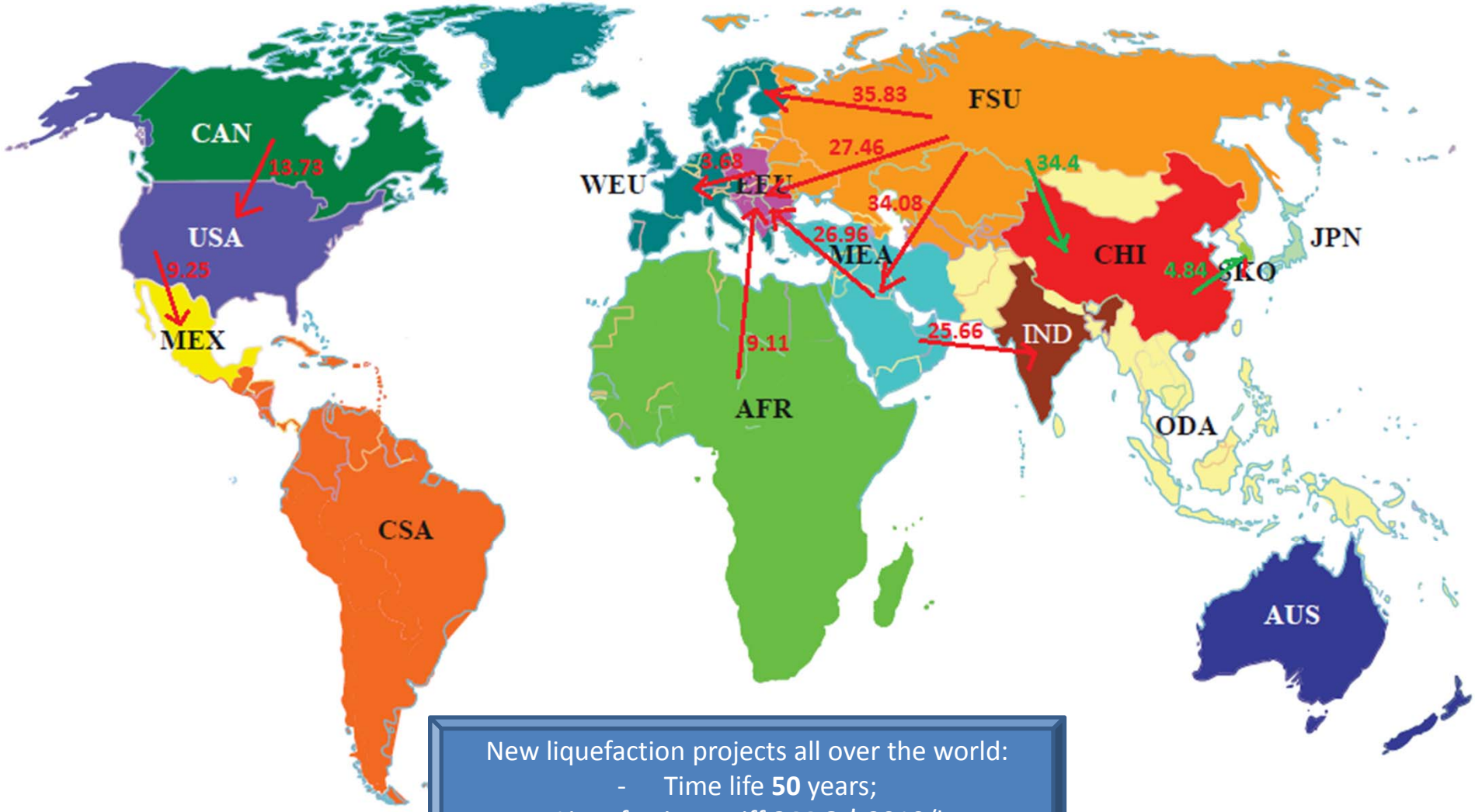


Regions	CHI	CSA	EEU	FSU	MEA	WEU	Pset_PN
	0.0			0.0			TU_GASNGA_FSU_CHI_01
			0.0	0.0			TU_GASNGA_FSU_EEU_01
				0.0	0.0		TU_GASNGA_FSU_MEA_01
				0.0		0.0	TU_GASNGA_FSU_WEU_01
	0.1			0.1			TU_GASNGA_FSU_CHI_01
			0.1	0.1			TU_GASNGA_FSU_EEU_01
				0.1	0.1		TU_GASNGA_FSU_MEA_01
				0.1		0.1	TU_GASNGA_FSU_WEU_01
	1,150.0			1,150.0			TU_GASNGA_FSU_CHI_01
	1,150.0			1,150.0			TU_GASNGA_FSU_CHI_01
	0.1			0.1			TU_GASNGA_FSU_CHI_01
			0.1	0.1			TU_GASNGA_FSU_EEU_01
				0.1	0.1		TU_GASNGA_FSU_MEA_01
				0.1		0.1	TU_GASNGA_FSU_WEU_01
				1,101.9		1,101.9	TU_GASNGA_FSU_WEU_01
	7.0			7.0			TU_GASNGA_FSU_CHI_01
			5.6	5.6			TU_GASNGA_FSU_EEU_01
				6.9	6.9		TU_GASNGA_FSU_MEA_01
				7.3		7.3	TU_GASNGA_FSU_WEU_01
	0.3			0.3			TU_GASNGA_FSU_CHI_01
			0.3	0.3			TU_GASNGA_FSU_EEU_01
				0.3	0.3		TU_GASNGA_FSU_MEA_01
				0.4		0.4	TU_GASNGA_FSU_WEU_01
	50.0			50.0			TU_GASNGA_FSU_CHI_01
			50.0	50.0			TU_GASNGA_FSU_EEU_01
				50.0	50.0		TU_GASNGA_FSU_MEA_01
				50.0		50.0	TU_GASNGA_FSU_WEU_01

	NCAP_TLIFE	2000							
	PRC_RESID	2000					100.0	100.0			TU_GASNGA_FSU_EEU_01
	PRC_RESID	2000						8,254.0		8,254.0	TU_GASNGA_FSU_WEU_01
	PRC_RESID	2000						1,362.3	1,362.3		TU_GASNGA_FSU_MEA_01
	PRC_RESID	2005					100.0	100.0			TU_GASNGA_FSU_EEU_01
	PRC_RESID	2005						8,254.0		8,254.0	TU_GASNGA_FSU_WEU_01
	PRC_RESID	2005						1,362.3	1,362.3		TU_GASNGA_FSU_MEA_01
	PRC_RESID	2100			0.1			0.1			TU_GASNGA_FSU_CHI_01
	PRC_RESID	2100					0.1	0.1			TU_GASNGA_FSU_EEU_01
	PRC_RESID	2100						0.1			TU_GASNGA_CAC_FSU_01
	PRC_RESID	2100						0.1	0.1		TU_GASNGA_FSU_MEA_01
	PRC_RESID	2100						0.1		0.1	TU_GASNGA_FSU_WEU_01
	ACT_BND	2000						50.0			TU_GASNGA_FSU_EEU_01
	ACT_BND	2000						4,745.3			TU_GASNGA_FSU_WEU_01
	ACT_BND	2000						518.9			TU_GASNGA_FSU_MEA_01
	ACT_BND	2005						50.0			TU_GASNGA_FSU_EEU_01
	ACT_BND	2005						5,244.9			TU_GASNGA_FSU_WEU_01
	ACT_BND	2005						946.8			TU_GASNGA_FSU_MEA_01
	ACT_BND	2050						0.5			TU_GASNGA_FSU_EEU_01
	ACT_BND	2050						0.1			TU_GASNGA_FSU_MEA_01

2. TIAM -> input data

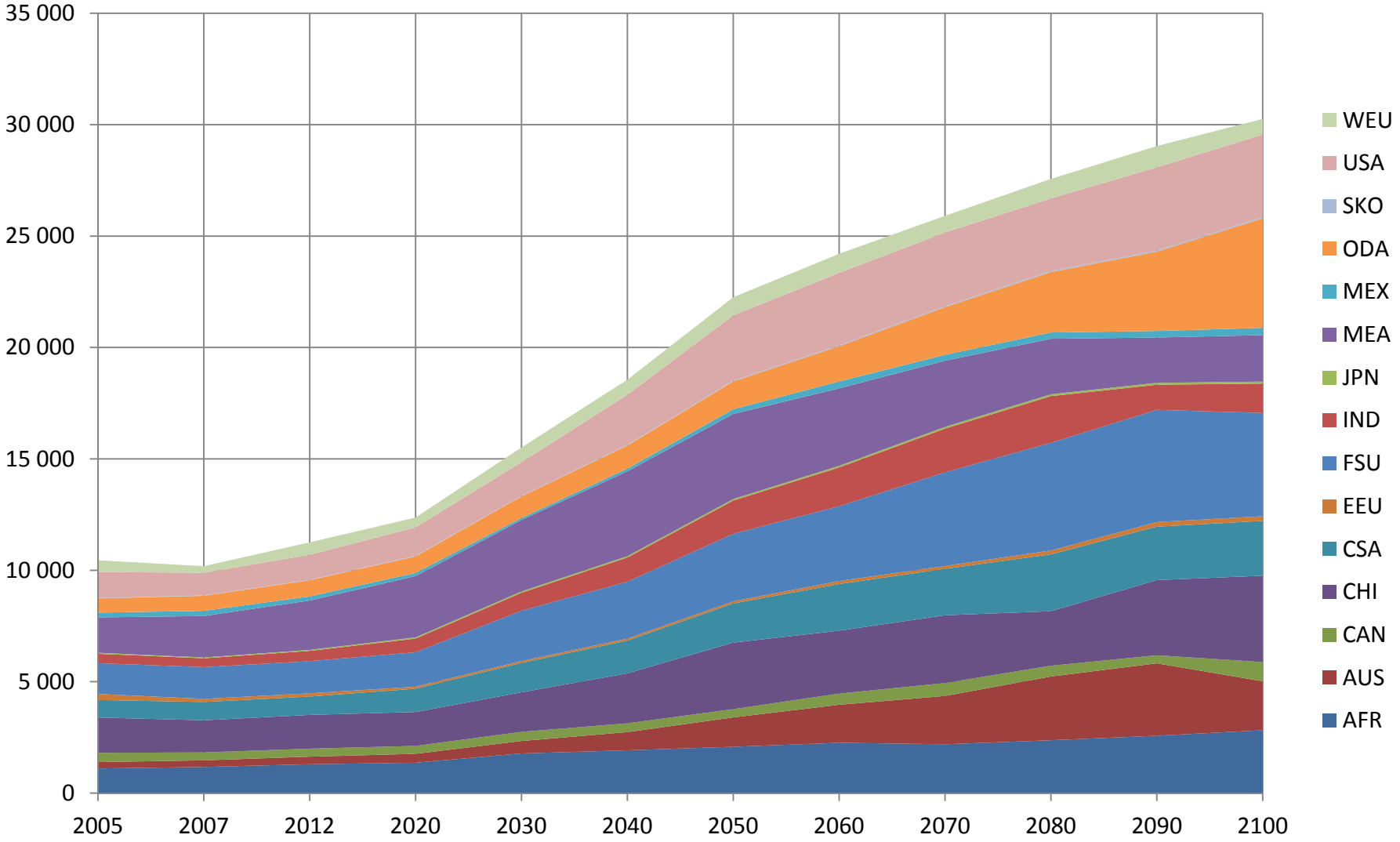
Inter-regional gas pipeline transport cost, $ 2010/thousand cubic meters



New liquefaction projects all over the world:
- Time life **50** years;
- Liquefaction tariff **244.8 $** 2010/kcm

2. TIAM -> base case results

TPES, mtoe



2. TIAM -> base case results

World TPES base case results in comparison with IEA WEO 2010 projections

Fuel type, mtoe	TIAM 2005	IEA stat 2005	TIAM 2020	WEO 2020	TIAM 2030	WEO 2030
Biomass	1,225	1,121	1,665	1,461-1,539	2,305	1,621-2,022
Coal	2,723	2,888	3,297	3,743-4,307	3,902	2,714-4,932
Gas	2,493	2,363	3,306	2,960-3,166	5,405	3,106-3,722
Hydro	251	251	334	364-383	383	416-483
Nuclear*	232	722	222	915-1,003	254	1,040-1,495
Oil	3,504	4,009	3,348	4,175-4,443	2,833	3,975-4,826
Other renewables	21	62	196	239-325	433	384-789
TOTAL	10,450	11,425	12,368	14,127-14,896	15,515	14,584-16,941

* - Nearly 3-time difference in nuclear energy can be explained by the IEA statistical conversion factor for nuclear energy (33%)

2. TIAM -> base case results

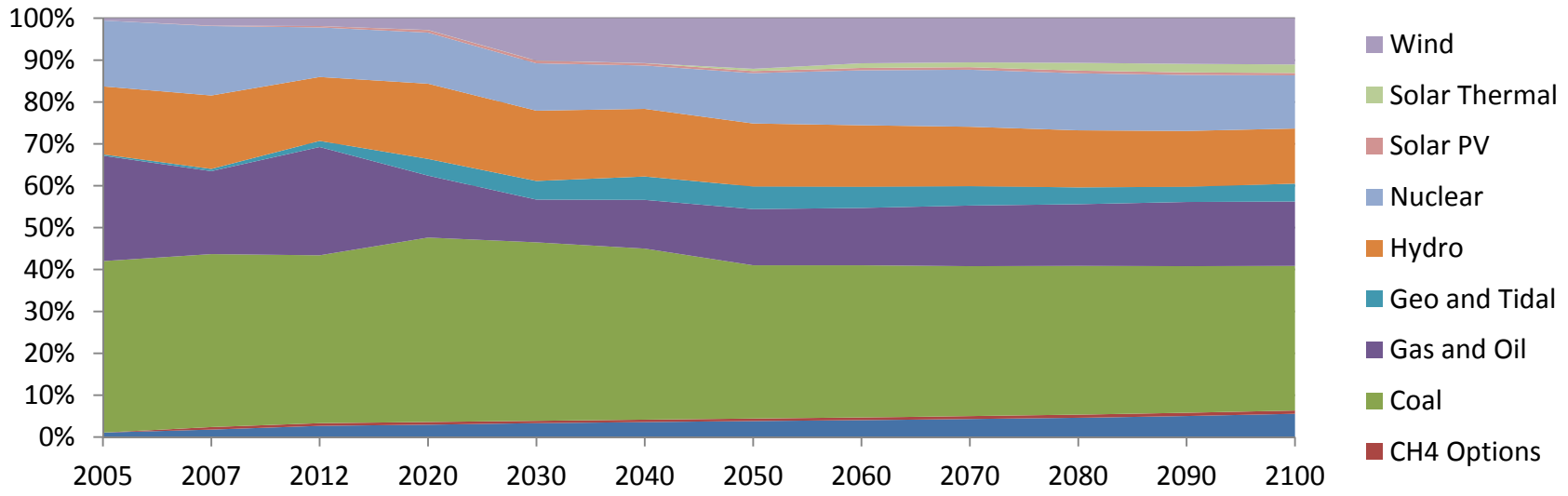
World TFC demand in comparison with the IEA WEO 2010 projections

Sector/fuel type, mtoe	TIAM 2005	IEA stat 2005	TIAM 2020	WEO 2020	TIAM 2030	WEO 2030
TFC	**7,034**	**7,878**	**8,860**	**9,779-10,224**	**10,883**	**10,257-11,544**
Coal	582	665	1,047	997-1,072	1,376	904-1,123
Oil	2,840	3,420	2,785	3,751-3,985	3,058	3,650-4,439
Gas	1,154	1,225	2,030	1,486-1,565	2,680	1,563-1,765
Electricity	1,209	1,293	1,487	1,933-2,040	1,873	2,230-2,548
Heat	209	268	198	281-297	202	262-317
Biomass	1,027	986	1,255	1,234-1,285	1,604	1,299-1,543
Other ren	14	11	59	31-46	90	54-105
Industry	**2,216**	**2,098**	**3,385**	**2,967-3,132**	**4,395**	**3,076-3,512**
Coal	478	518	989	811-876	1,284	750-937
Oil	354	327	312	351-380	392	321-384
Gas	571	425	1,098	556-587	1,578	592-658
Electricity	501	532	676	857-908	826	971-1,115
Heat	85	115	39	128-134	21	120-141
Biomass	219	177	264	246-264	291	276-321
Other ren	7	0	5	1-1	5	1-1
Transport	**2,069**	**2,175**	**2,286**	**2,588-2,710**	**2,746**	**2,770-3,182**
Coal	4	4	12	-	21	-
Oil	2,026	2,060	2,068	2,336-2,483	2,196	2,292-2,891
Gas	8	70	122	-	225	-
Electricity	19	22	23	34-38	27	46-80
Heat	0	0	0	-	0	-
Biomass	12	19	60	107-122	277	142-283
Other ren	0	0	0	-	0	-
Other	**2,749**	**2,884**	**3,190**	**4,224-4,382**	**3,742**	**4,411-4,850**
Coal	99	114	45	-	71	-
Oil	460	489	405	1,064-1,123	471	1,037-1,163
Gas	574	597	810	-	877	-
Electricity	688	739	787	1,038-1,097	1,020	1,179-1,387
Heat	125	153	159	-	181	-
Biomass	796	790	930	881-899	1,037	880-939
Other ren	7	10	54	-	85	-

2. TIAM -> base case results

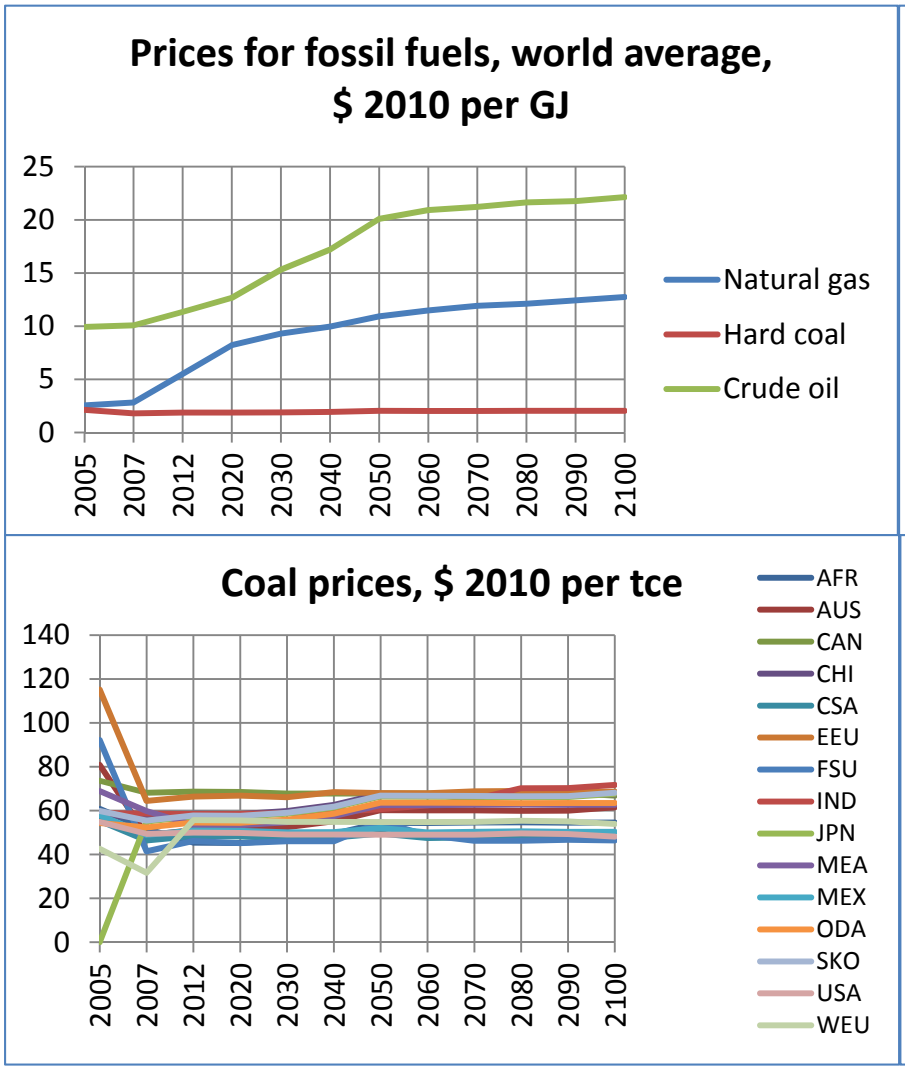
Generation by fuel type, TWh*h

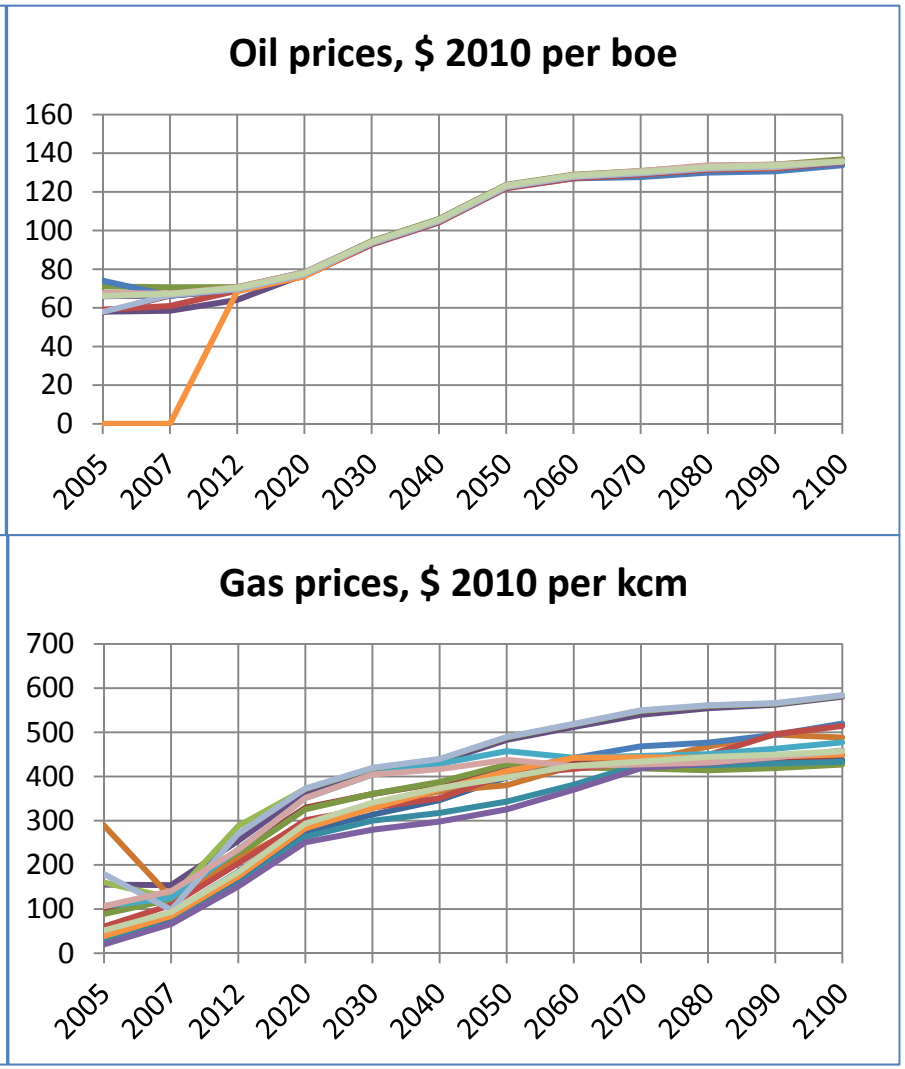
Fuel type	2005	2007	2012	2020	2030	2040	2050	2060	2070	2080	2090	2100
Biomass	183.6	281.5	504.5	620.4	853.6	1,141.6	1,507.6	1,770.6	2,071.6	2,435.9	2,833.2	3,333.5
CH4 Options	0.0	97.8	118.8	136.7	142.5	183.1	251.4	295.7	334.9	367.0	430.6	463.8
Coal	7,042.9	6,566.4	7,592.5	9,289.2	11,040.9	12,973.3	14,553.8	16,002.0	17,254.0	18,692.9	19,731.5	20,693.5
Gas and Oil	4,336.6	3,149.4	4,898.5	3,126.2	2,645.5	3,688.5	5,325.8	6,036.0	6,984.2	7,752.0	8,638.7	9,200.0
Geo and Tidal	56.5	86.9	276.5	839.2	1,148.4	1,772.5	2,152.6	2,218.7	2,235.9	2,102.6	2,034.4	2,567.0
Hydro	2,788.7	2,788.7	2,890.2	3,788.1	4,354.7	5,132.7	5,974.8	6,465.1	6,834.7	7,179.5	7,523.9	7,874.3
Nuclear	2,701.7	2,631.8	2,243.9	2,579.7	2,927.3	3,286.2	4,782.2	5,782.4	6,573.9	7,169.2	7,538.3	7,599.9
Solar PV	2.3	18.9	63.0	128.4	167.8	174.7	208.0	250.6	289.1	322.0	345.0	354.2
Solar Thermal	0.2	0.2	2.1	8.2	8.3	9.0	211.4	497.7	549.1	981.5	1,128.1	1,201.5
Wind	95.8	280.5	351.9	586.9	2,610.0	3,406.9	4,797.3	4,737.1	5,083.5	5,604.1	6,154.7	6,626.4
Total	17,208.3	15,902.2	18,942.0	21,103.2	25,899.0	31,768.5	39,764.9	44,055.9	48,211.0	52,606.6	56,358.3	59,914.0



2. TIAM -> base case results

Dual prices for fossil fuels (gas, oil and coal)



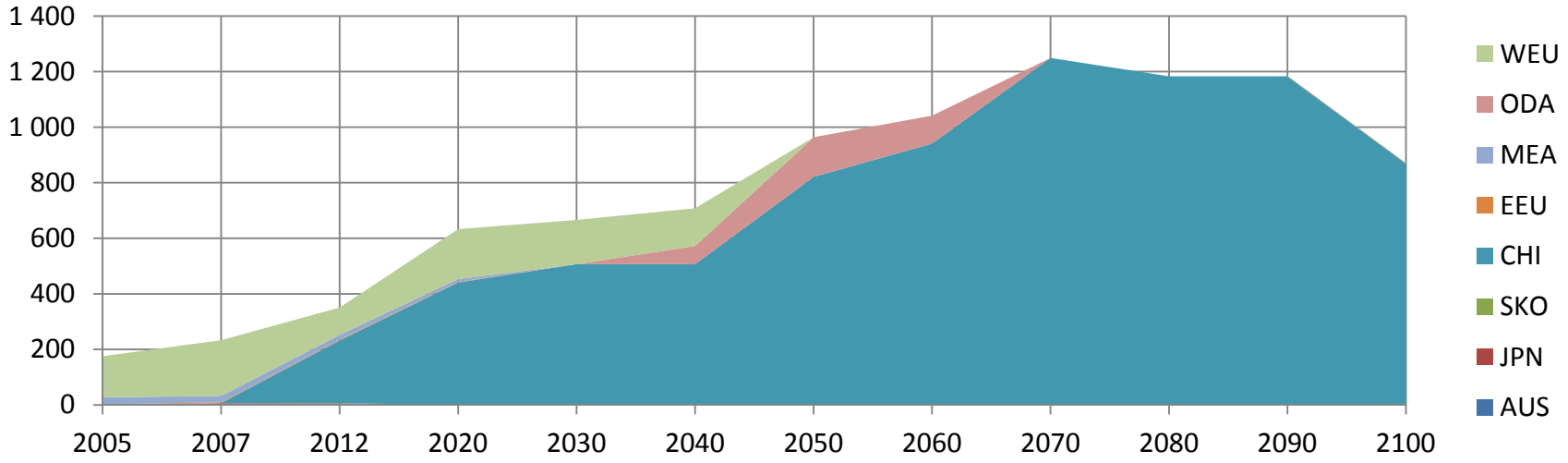


2. TIAM -> base case results

Gas export from FSU, bcm

Type	Importer	2005	2007	2012	2020	2030	2040	2050	2060	2070	2080	2090	2100
LNG	AUS	0.0	4.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LNG	JPN	0.0	2.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LNG	SKO	0.0	0.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LNG	TOTAL LNG	0.0	6.8	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pipeline	CHI	0.0	0.0	225.2	440.8	507.0	507.0	820.9	941.1	1,249.1	1,182.9	1,182.9	869.0
Pipeline	EEU	2.6	2.6	2.4	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pipeline	MEA	24.7	22.7	17.8	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pipeline	ODA	0.0	0.0	0.0	0.0	0.0	65.2	142.9	100.4	0.0	0.0	0.0	0.0
Pipeline	WEU	148.2	201.0	98.6	179.9	158.8	136.1	0.0	0.0	0.0	0.0	0.0	0.0
Pipeline	TOTAL Pipeline	175.6	226.3	344.0	632.7	665.8	708.3	963.8	1,041.4	1,249.1	1,182.9	1,182.9	869.0
TOTAL	TOTAL	175.6	233.2	350.9	632.7	665.8	708.3	963.8	1,041.4	1,249.1	1,182.9	1,182.9	869.0

By directions



3. Further model usage -> Scenario calculation

Pipeline gas export from FSU, bcm by scenarios:

- ET_Ref – base case, calculated by ERI RAS
- ET_Ref_1303 – base case, downloaded from kanors
- ET_Ref_FSU_CHI_BND – ERI RAS case with the modified export capacity and costs data

Table Name: T_91201180400PM													
Active Unit: bcm													
Scenario	Process\Period	2005	2007	2012	2020	2030	2040	2050	2060	2070	2080	2090	2100
ET_Ref	MINBIOGAS0	3.7	0.0	5.1	0.1	0.1	1.8	0.0	0.0	0.0	13.1	11.7	13.1
ET_Ref	TU_GASLNG_AUS_CHI_01	0.0	4.3	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	196.1	580.0
ET_Ref	TU_GASLNG_MEA_CHI_01	0.0	1.4	2.2	0.0	110.8	605.8	569.7	474.6	2.6	169.3	1.7	1.7
ET_Ref	TU_GASNGA_FSU_CHI_01	0.0	0.0	227.9	446.1	529.2	529.2	807.2	880.1	1,288.5	1,205.4	1,205.4	927.5
ET_Ref_1303	MINBIOGAS0	3.7	0.0	5.1	0.1	0.1	1.8	0.0	0.0	0.0	13.1	10.6	13.1
ET_Ref_1303	TU_GASLNG_AUS_CHI_01	0.0	4.3	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	232.2	612.1
ET_Ref_1303	TU_GASLNG_MEA_CHI_01	0.0	1.4	2.2	0.0	124.0	586.3	549.1	454.2	0.0	140.6	1.7	1.7
ET_Ref_1303	TU_GASLNG_ODA_CHI_01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	164.2
ET_Ref_1303	TU_GASNGA_FSU_CHI_01	0.0	0.0	225.2	440.8	507.0	507.0	820.9	941.1	1,249.1	1,182.9	1,182.9	869.0
ET_Ref_FSU_CHI_BND	MINBIOGAS0	3.7	0.0	5.1	0.1	0.1	1.8	0.0	10.0	13.1	13.1	13.1	13.1
ET_Ref_FSU_CHI_BND	TU_GASLNG_AUS_CHI_01	0.0	4.3	6.5	0.0	0.0	0.0	9.1	0.0	112.4	588.2	615.9	615.9
ET_Ref_FSU_CHI_BND	TU_GASLNG_MEA_CHI_01	0.0	1.4	169.4	296.6	607.4	903.0	1,128.2	949.4	712.1	499.0	174.2	74.8
ET_Ref_FSU_CHI_BND	TU_GASLNG_ODA_CHI_01	0.0	0.0	0.0	0.0	0.0	0.0	18.5	167.1	167.1	167.1	687.8	687.8
ET_Ref_FSU_CHI_BND	TU_GASNGA_FSU_CHI_01	0.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

Due to the lack of pipeline gas from the FSU, China has moved to import LNG from the Middle East. Such «unreal» import and export results are possible because of the far too large world fossil fuels supply capabilities used in the TIAM model.

Alexander Goryachev,
Modelling expert

Thanks for attention

Energy Research Institute of the Russian Academy of Sciences (ERIRAS)