



Development of Korean Off-site Consequence Analysis Code Package [KOSCA-MACCS2]

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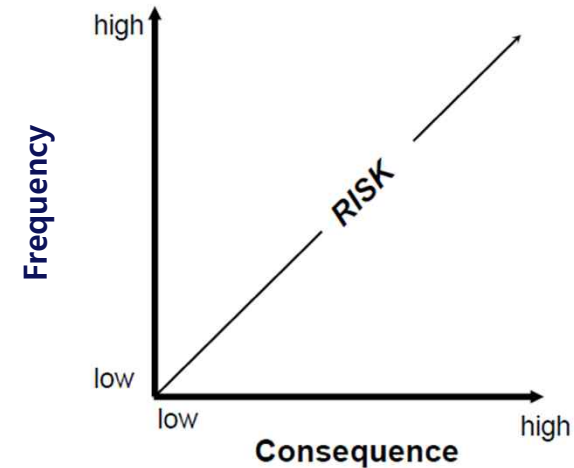
- 1 Background (L3 PSA 관련 국내 현황)
- 2 KOSCA-MACCS2 개요
- 3 결론

※ KOSCA-MACCS2: Korean Off-Site Consequence Analysis based on MACCS2
※ MACCS2: MELCOR based Accident Consequence Code System II

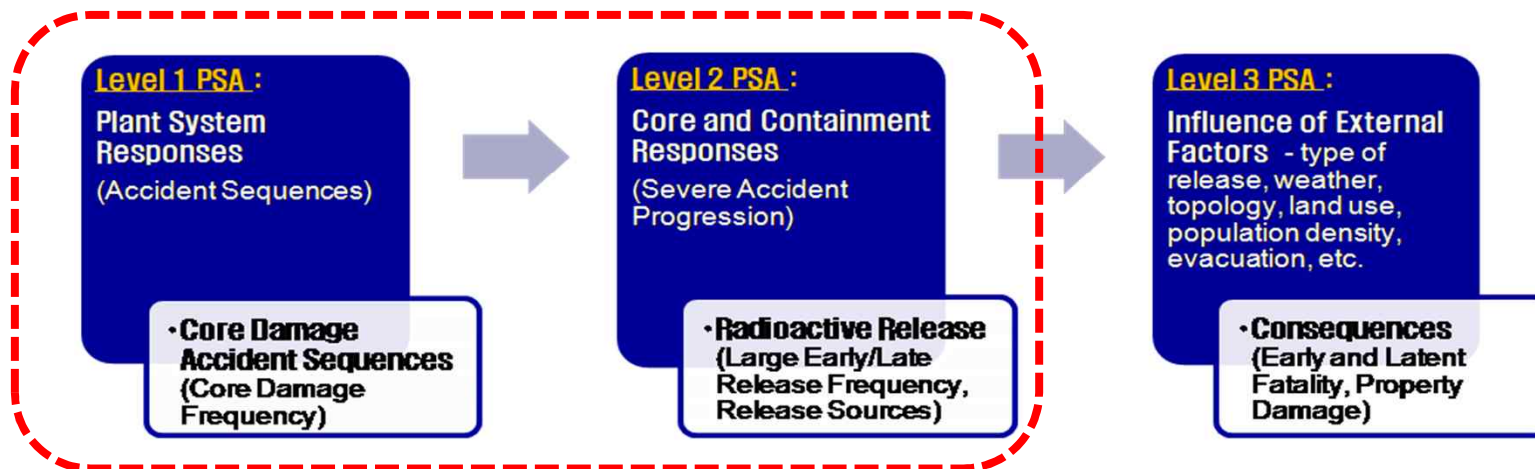
Measure of Safety



- ❖ Risk (to the public)
= Frequency X Consequence
- ❖ Use of risk surrogates
 - Core Damage Frequency
 - Early Release Frequency



❖ Three Levels of PSA



국내외 PSA 현황 비교 (as of 2012)



Plant (Project)	Plant Type	1단계 PSA				2단계 PSA				3단계 PSA				비고
		전출력(FP)		정지(SD)		FP		SD		FP		SD		
		내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	
고리 1	W PWR	O	O	X	X	O	O	X	X	X	X	X	X	
고리 2	W PWR	O	O	X	X	O	O	X	X	X	X	X	X	
고리 3,4	W PWR	O	O	X	X	O	O	X	X	X	X	X	X	
영광 1,2	W PWR	O	O	X	X	O	O	X	X	X	X	X	X	
영광 3,4	Sys80	O	O	X	X	O	O	X	X	X	X	X	X	
영광 5,6	OPR-1000	O	O	O	X	O	O	X	X	X	X	X	X	
울진 1,2	Framatome	O	O	X	X	O	O	X	X	X	X	X	X	
울진 3,4	OPR-1000	O	O	X	X	O	O	X	X	X	X	X	X	
울진 5,6	OPR-1000	O	O	O	X	O	O	X	X	X	X	X	X	
신고리 1,2	OPR+	O	O	O	X	O	O	X	X	X	X	X	X	건설중 PSA
신고리 3,4	APR-1400	O	O	O	O	O	O	O	O	O	O	X	X	건설중 PSA
월성 1	CANDU	O	O	X	X	O	O	X	X	X	X	X	X	
월성 2,3,4	CANDU	O	O	X	X	O	O	X	X	X	X	X	X	
신월성 1,2	OPR+	O	O	O	X	O	O	X	X	X	X	X	X	건설중 PSA

주1) 2012년 기준 O(수행), X(미수행),

주2) 외부사건은 지진, 화재, 침수사건에 국한

주3) 고리1,2, 울진1, 월성1,2 FP 1단계 지진은 SMA(seismic margin analysis)적용. 해당 원전의 FP 2단계 지진 PSA 미수행.

주4) 영광3,4,5,6, 울진3,4,5,6, 신고리1,2, 신월성1,2의 FP 1,2단계 화재사건은 선별제거(screen out)됨.

리스크 프로파일 참조표준 (Project)	Plant Type	1단계 PSA				2단계 PSA				3단계 PSA				비고
		전출력(FP)		정지(SD)		FP		SD		FP		SD		
		내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	내부사건	외부사건	
WASH-1400 (RSS, 1975)	PWR	O	O	X	X	O	O	X	X	O	O	X	X	추1)
	BWR	O	O	X	X	O	O	X	X	O	O	X	X	
NUREG 1150 (SAR, 1990)	PWR	O	O	O	O	O	O	O	O	O	O	O	O	추2)
	BWR	O	O	O	O	O	O	O	O	O	O	O	O	

주1) SFP, 액체 및 기체폐기물탱크, 사보타지 포함, 주2) SD PSA: PWR-Surry (NUREG/CR-6144, 1995), BWR-Grand Gulf (NUREG/CR-6143, 1995)

Status of Domestic Level 3 PSA



❖ Pre-Fukushima Accident

- Determination of safety goal (중대사고정책 (2001)) without any domestic-specific results of Level 3 analysis
- Practically use of risk surrogates
 - No need to Level 3 PSA
 - No infrastructure for performing domestic Level 3 PSA

❖ Post-Fukushima

- Multi-unit site risk issued
- On-going rule-making related to Level 3
 - 원자력안전법(2014) → Level 1/2/3 PSA in SAR
 - 방사선영향평가보고서(RER)에서 사고영향평가 범위 확대 논의

L3 PSA 현안



❖ To establish the infrastructure for domestic Level 3 PSA

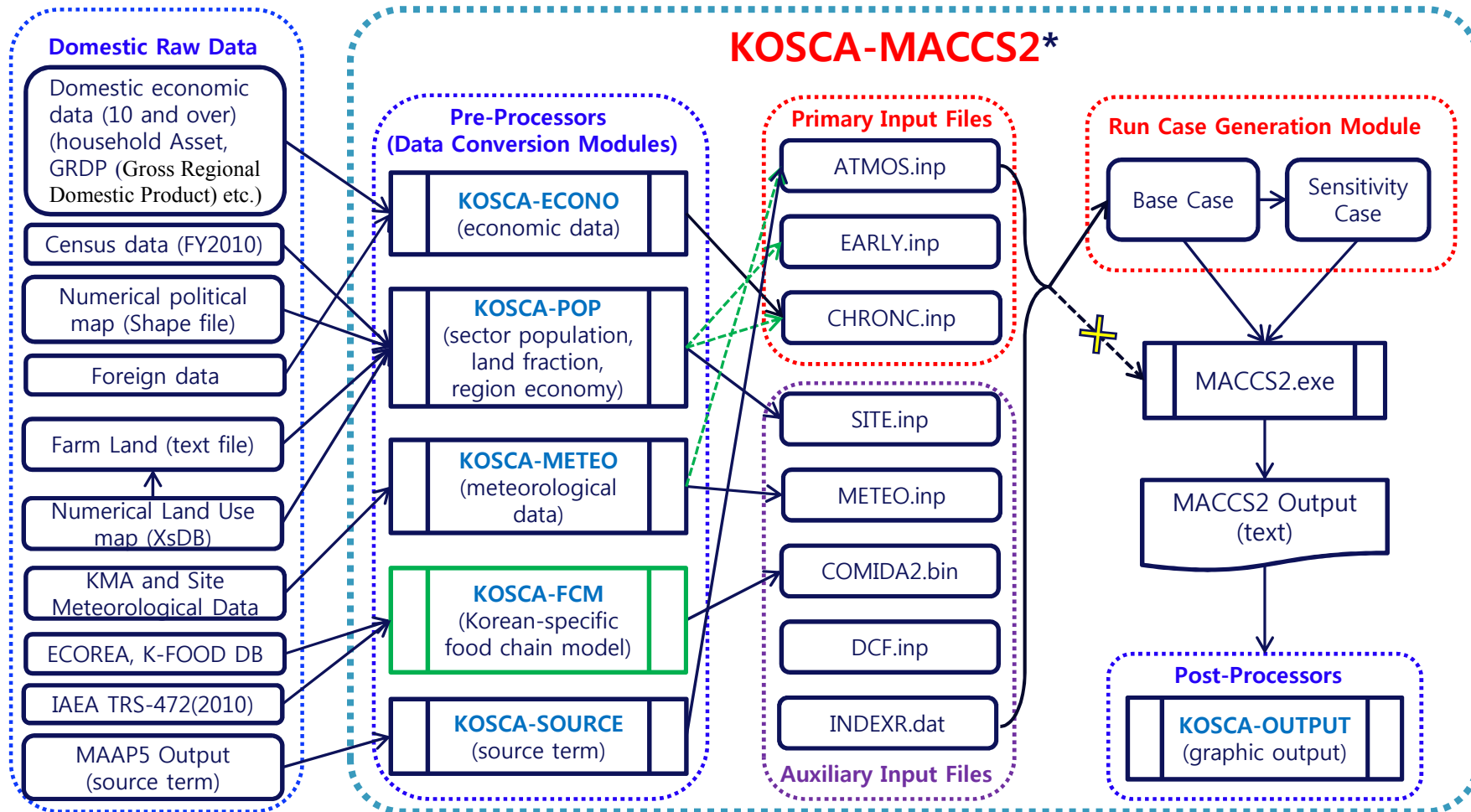
❖ 4차 원자력연구개발사업(2012.3-2017.2)

- 국내 고유 Level 3 PSA 기술현안 연구 (2012.3-2015.2)
 - 선량변환계수(DCF) 및 대기확산모델의 국내 기술적 적합성 연구
 - 국내고유 음식섭취모델(FCM) 및 DB 개발
 - 국내고유 경제성영향평가 모델 및 DB 개발
- **MACCS2 기반 국내고유 L3 PSA 수행용 전산체계(KOSCA-MACCS2) 구축 (2012.3-2016.2)**
 - 통합버전 (w/ 5개 pre-processors & 1개 post-processor)

※ KOSCA-MACCS2: Korean Off-Site Consequence Analysis based on MACCS2

※ MACCS2: MELCOR based Accident Consequence Code System II

Overview of KOSCA-MACCS2



* SW 개발 참여 업체 : 한국신뢰성기술(주)

Overview of KOSCA-MACCS2



❖ 주요 기능 및 특징

- Provide user-interface for managing site-specific MACCS2 input/output files
 - Project 단위, tree 구조 관리 방식
 - Run case generation module
 - base case, sensitivity case, batch run for the cases selected
 - Help function

 - Facilitate to prepare the domestic site-specific MACCS2 inputs by five pre-processors
 - KOSCA-POP (vs SECPOP2000): sector population, land fraction, region indexing and regional economy data generation module
 - KOSCA-ECONO: economic cost data conversion module
 - KOSCA-MEREO: meteorological data conversion module
 - KOSCA-FCM: domestic food chain model (input DB for COMIDA2)
 - KOSCA-SOURCE: MAAP5 source term conversion module
- ※ No development of DCF pre-processor (just using MACCS2 DCF inputs generated by FRGDCF, IDCF2 and DOSFAC2)*

Overview of KOSCA-MACCS2



❖ 주요 기능 및 특징 (*continued*)

- Facilitate to interpret and document MACCS2 outputs visually by a post-processor, KOSCA-OUTPUT
 - converting MACCS2 text outputs (16 types) to graphic forms (scatter diagram like bar chart, complementary cumulative density function(CCDF))

❖ KOSCA-MACCS2 권장 시스템 사양

Type	Requirements for KOSCA-POP module	Requirements for main and other modules
OS	Windows 7 and over, 64 bit OS	Windows XP and over
Hardware	RAM : 6GB and over (min. 4GB)	RAM : 2GB and over
System Environment	Microsoft .Net framework 4.0 and over	

KOSCA-MACCS2 데모



MACCS2 execution

Project Case: KORI-01-20141126-wskim-B01(001)

Base_Name	Base_Code	BaseCase_code	ATMOS_C
801	001	001	ATMOS

```

C:\Windows\system32\cmd.exe
For Julian Day 339, selecting COMIDA2 results # 1 of 9
Condemn farmland at 1
Condemn farmland at 2
Condemn farmland at 3
Condemn farmland at 4
Condemn farmland at 5
Condemn farmland at 6
Condemn farmland at 7
3 years of farm interdiction at 8
2 years of farm interdiction at 9
1 years of farm interdiction at 10
ITRIAL= 85
For Julian Day 339, selecting COMIDA2 results # 1 of 9
Condemn farmland at 1
Condemn farmland at 2
Condemn farmland at 3
Condemn farmland at 4
Condemn farmland at 5
Condemn farmland at 6
Condemn farmland at 7
6 years of farm interdiction at 8
2 years of farm interdiction at 9
1 years of farm interdiction at 10
ITRIAL= 86
    
```

Project Code: KORI-04-20141117-wskim

Output Group: B34

Output File: C:_PSA_Data\KORI-04-20141117-wskim\Run_Base\WB34W001\KORI-04-20141117-wskim_B34-001-OUTPUT

MACCS2 11/17/2014 15:52:04 VERSION 1.12

P1: ATMOS USER INPUT (UNIT 24) = atmos.inp
 P2: EARLY USER INPUT (UNIT 25) = early.inp
 P3: CHRONC USER INPUT (UNIT 26) = chronc.inp
 P4: METEOROLOGY DATA (UNIT 28) = meteo.inp
 P5: SITE DATA INPUT (UNIT 29) = site.inp
 P6: LIST OUTPUT (UNIT 06) = output

USER INPUT IS READ FROM UNIT 24
 RECORD IDENTIFIER FIELDS: 11 CHARACTERS LONG ARE EXPECTED.
 THE FIRST 100 COLUMNS OF EACH INPUT RECORD ARE PROCESSED.
 THE MAXIMUM NUMBER OF IDENTIFIER RECORDS THAT MAY BE SAVED AS THE
 BASE CASE IS 1000.

RECORD NUMBER RECORD
 * GENERAL DESCRIPTIVE TITLE DESCRIBING THIS "ATMOS" INPUT
 1 RIATNAM1001 'ATMOS input for UCN 384'

* GEOMETRY DATA BLOCK, LOADED BY INPGeo, STORED IN /GEOM/
 *

ERL FAT: 8.0 km

Graph: KORI-04.20141117-wskim / B34 / 001 (ERL FAT - 8.0 km)

Y-axis: Exceedance Probability (log scale from 10E-14 to 10E-2)

X-axis: Early Fatalities Risk (log scale from 10E-15 to 10E+15)

❖ Functions

- Identification of polar-coordinate spatial grid
- Calculation of sector population and land fraction
- Region index and regional economic data

❖ Identification of polar-coordinate spatial grid

- depends on the limit of MACCS2 version (e.g., MACCS2 V1.6 경우 compass directions ≤ 64 , intervals ≤ 35)
- Region Index & economic data: 자동 할당 (시군구 단위)

❖ Land Fraction

- 수치 토지 피복도(Land Use Digital Map)로부터 변환한 30m X 30m point data(~10GB text format) 활용 → land fraction 기초 자료 추출 (~2.7GB)

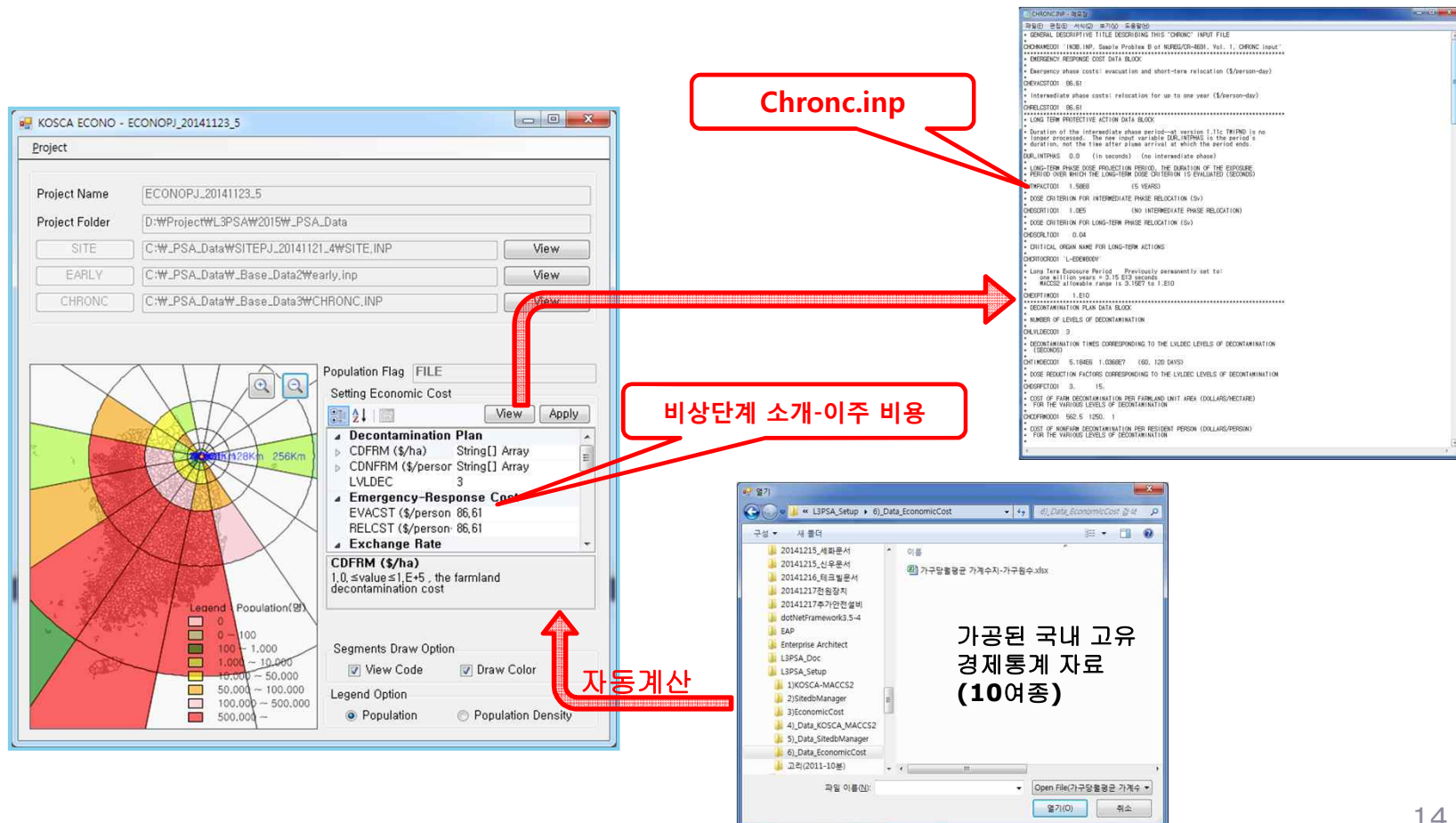
❖ Sector Population

- 2010 센서스 자료
- 법정동 수치지도 (동/읍/면 수준)
- Center point 좌표 입력 방식 3가지 (TM 좌표계로 변환 사용)
- 3가지 알고리즘 적용 가능 (vs. SECPOP block-level & county-level)
 - Allocation of population by the ratio of area belonging to the sector (Area)
 - Allocation of population to the sector containing center point of administrative district (Center)
 - The use of the 1km² point data (Point)
- 계산 결과 비교 (전국, 16방위 10개 구간)

	Area	Center	Point
인구수(48,582,293; 통계청자료) 2010_법정동인구_코드_동명.csv	48,582,293	48,367,271.38	50,911,697.65
면적(101,160.69; 통계청자료) 2010_법정동_TM_코드_동명.txt	101,160.69	101,151.34	101,151.34
인구오차(%)	~0	-0.44	4.79
면적오차(%)	~0	-0.009	-0.009
소요시간	4~7시간	5~10분	5~10분

❖ 통계청 자료 활용 (2010년 자료 10여종 이상)

- 국내 경제통계자료는 대개 군/구/시 수준 (일부자료는 도/광역시 자료)
- 단, 제염비용은 국외 사례 자료(체르노빌, Estern-E 자료 등)



The screenshot displays the KOSCA ECONO software interface. On the left, the 'Project' settings are visible, including 'Project Name' (ECONOPJ_20141123_5) and 'Project Folder'. Below this is a map showing a circular area with concentric rings and a legend for 'Population (명)'. The legend includes categories like 0-100, 100-1,000, 1,000-10,000, 10,000-50,000, 50,000-100,000, 100,000-500,000, and 500,000+.

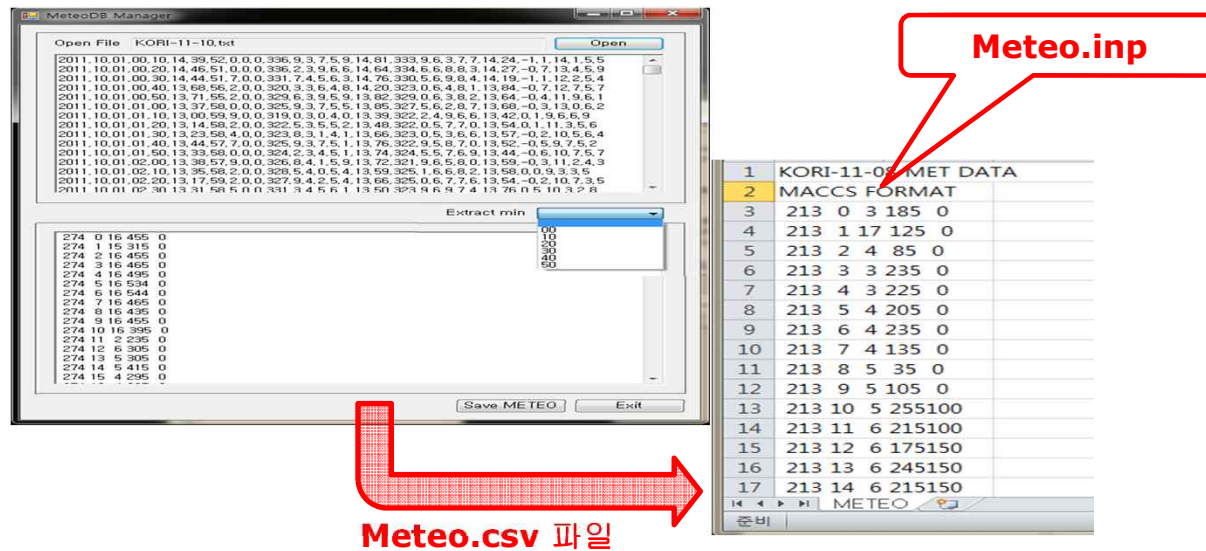
In the center, the 'Setting Economic Cost' panel is active, showing 'Decontamination Plan' and 'Emergency-Response Cost' settings. A red callout box labeled '비상단계 소개-이주 비용' (Emergency phase introduction-relocation cost) points to the 'Emergency-Response Cost' section.

On the right, a text editor window shows the 'Chronc.inp' file content, which includes parameters for emergency response costs, decontamination levels, and other economic factors. A red callout box labeled 'Chronc.inp' points to this window.

At the bottom, a file explorer window shows a folder structure with files like '20141215_세화문서', '20141215_산유문서', etc. A red callout box labeled '자동계산' (Automatic calculation) points to this window. Another red callout box labeled '가공된 국내 고유 경제통계 자료 (10여종)' (Processed domestic unique economic statistics data (10+ types)) points to the file explorer.

❖ 기상자료 변환 모듈

- MACCS2용 기상자료: 발전소 기상관측자료
 - 6년치 10분간격 관측자료(~2011.12)
- CALMAT용 기상자료: 기상청(KMA) 전국 관측소 자료
 - 5년치 20분간격 관측자료(~2011.12)



MeteoDB Manager

Open File KORI-11-10.txt

2011.10.01.00.10.14.39.52.0.0.336.9.3.7.5.9.14.81.333.9.6.3.7.7.14.24.-1.1.14.1.5.5
2011.10.01.00.20.14.46.51.0.0.336.2.3.9.6.6.14.64.334.6.6.8.8.3.14.27.-0.7.13.4.5.9
2011.10.01.00.30.14.44.51.7.0.331.7.4.5.6.3.14.76.330.5.6.9.8.4.14.19.-1.1.12.2.5.4
2011.10.01.00.40.13.68.56.2.0.0.320.3.3.5.4.8.14.20.323.0.6.4.8.1.13.84.-0.7.12.7.5.7
2011.10.01.00.50.13.71.55.2.0.0.325.6.3.9.5.9.13.82.329.0.6.3.8.2.13.64.-0.4.11.9.6.1
2011.10.01.01.00.13.37.58.0.0.325.9.3.7.5.5.13.85.327.5.6.2.8.7.13.69.-0.3.13.0.6.2
2011.10.01.01.10.13.00.59.9.0.0.319.0.3.0.4.0.13.39.322.2.4.9.6.6.13.42.0.1.9.6.6.9
2011.10.01.01.20.13.14.58.2.0.0.325.5.3.5.5.2.13.48.325.0.5.7.7.0.13.59.0.1.11.3.5.6
2011.10.01.01.30.13.23.58.4.0.0.323.8.3.1.4.1.13.66.323.0.5.3.6.6.13.57.-0.2.10.5.6.4
2011.10.01.01.40.13.44.57.7.0.0.325.9.3.7.5.1.13.76.322.9.5.8.7.0.13.52.-0.5.9.7.5.2
2011.10.01.01.50.13.33.68.0.0.0.324.2.3.4.5.1.13.74.324.5.5.7.6.9.13.44.-0.6.10.7.5.7
2011.10.01.02.00.13.38.57.9.0.0.326.8.4.1.5.9.13.72.321.9.6.5.8.0.13.59.-0.3.11.2.4.3
2011.10.01.02.10.13.38.58.2.0.0.326.6.4.0.5.4.13.63.325.1.6.6.8.2.13.68.0.0.9.3.3.5
2011.10.01.02.20.13.17.59.2.0.0.327.9.4.2.5.4.13.66.325.0.6.7.7.6.13.54.-0.2.10.7.3.5
2011.10.01.02.30.13.31.58.5.0.0.331.3.4.5.6.1.13.60.323.9.6.9.7.4.13.76.0.6.10.3.2.8

Extract min

274 0 16 455 0
274 1 15 315 0
274 2 16 455 0
274 3 16 465 0
274 4 16 495 0
274 5 16 534 0
274 6 16 544 0
274 7 16 465 0
274 8 16 435 0
274 9 16 455 0
274 10 16 395 0
274 11 2 235 0
274 12 6 305 0
274 13 5 305 0
274 14 5 415 0
274 15 4 295 0
274 16 1 225 0

Save METEO Exit

Meteo.inp

1	KORI-11-08 MET DATA				
2	MACCS FORMAT				
3	213	0	3	185	0
4	213	1	17	125	0
5	213	2	4	85	0
6	213	3	3	235	0
7	213	4	3	225	0
8	213	5	4	205	0
9	213	6	4	235	0
10	213	7	4	135	0
11	213	8	5	35	0
12	213	9	5	105	0
13	213	10	5	255100	
14	213	11	6	215100	
15	213	12	6	175150	
16	213	13	6	245150	
17	213	14	6	215150	

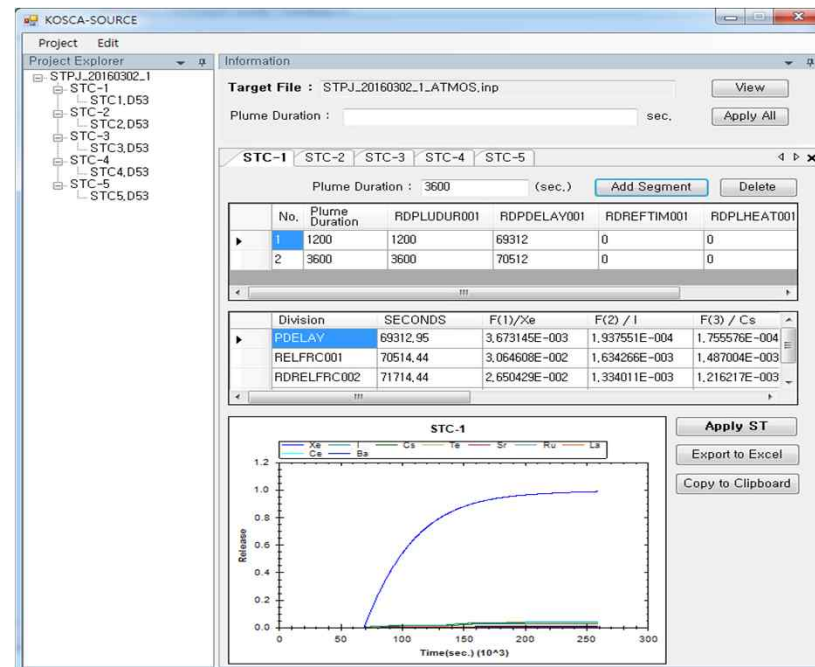
Meteo.csv 파일

KOSCA-SOURCE



- ❖ Source term analyses for PSA are usually performed by MAAP code in Korea
 - Differences: 18 ST groups for MAAP5, 9 for MACCS2
- ❖ The method for specifying the plumes analyzed (e.g., selection of the number of plume, release time, release duration, etc.) depends on the MACCS2 code (e.g., max. number of plumes ≤ 4 , etc.)

❖ KOSCA-SOURCE 예시 화면



KOSCA-OUTPUT



❖ The MACCS2 results (weather condition simulation) are written to binary files

- Representative statistics of the distribution for the result types (e.g., mean, mode and quantiles (50th, 90th, 95th, etc.))
- CCDF (optional)

❖ MACCS2 Result Types: 16종

- Type 0: atmospheric results at specified downwind distances
- Type 1: cases of specified health effect
- Type 2: early fatality radius
- Type 3: population exceeding dose threshold
- Type 4: average individual risk of health effects
- Type 5: total collective dose from material deposited within region
- Type 6: centerline dose versus distance
- Type 7: centerline risk versus distance
- Type 8: population-weighted safety goal risk
- Type A: max. observed dose at a specified distance ring (r) (direction-independent dose)
- Type B: max. observed dose at a specified (r, θ) location (direction-independent dose)
- Type 9: breakdown of CHRONC population dose by pathway
- Type 10: economic costs of mitigative actions
- Type 11: max. distance for the various mitigative actions
- Type 12: impacted area/population results
- Type 13: maximum individual dose from COMIDA2 food-chain model

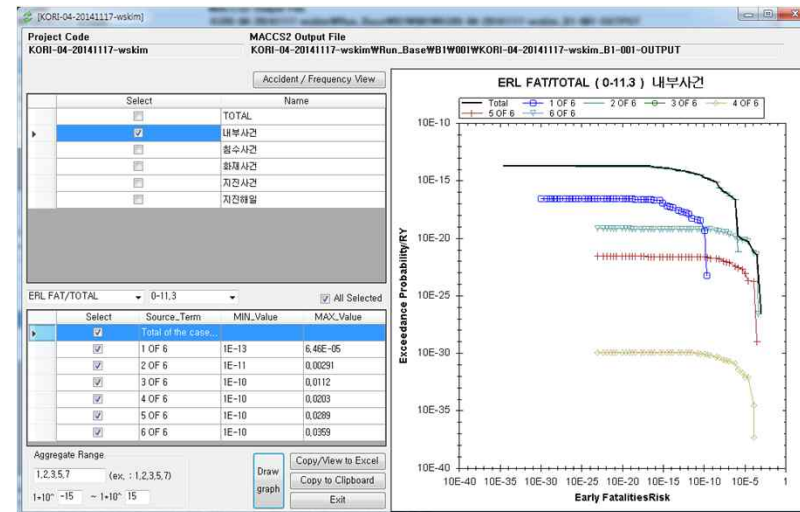
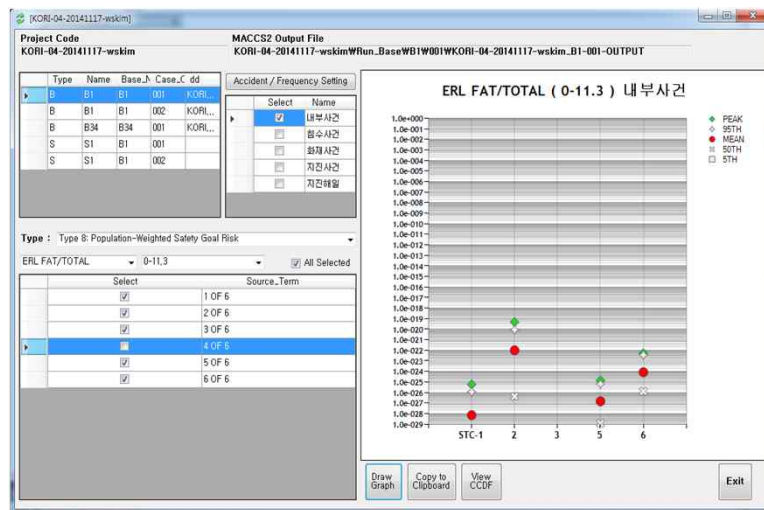
KOSCA-OUTPUT



❖ KOSCA-OUTPUT

- user interface to generate two types of graphs (scatter diagram and CCDF) from MACCS2 text output
- Auto-search function for the result types that user can select
- If necessary, the user can provide the frequency of the cases (e.g., ST categories) related to the result type

❖ KOSCA-OUTPUT 예시화면



- Level 3 PSA 중요성 증대
 - 국내 원자력 산업계 환경 변화 (규제체계 변화, 해외원전 수출)

- KOSCA-MACCS2 개발 완료(베타 버전)

- KOSCA-MACCS2 개발의 기대효과 및 활용
 - KOSCA pre- & post-processors를 활용한 국내 고유 소외 리스크 분석 가능
 - 한국형 소외 리스크 분석용 전산 코드(MACCS2 대체코드) 개발시 활용
 - 국방 및 타 산업체 연계 활용 (Toxic material + KOSCA-POP + 대기확산모델)

- Further Study
 - 국내고유 입력자료(인구, 수치지도, 경제성자료, 음식섭취 자료 등)의 유지 관리 체계 필요
 - 현행 risk profile의 개선 (cf. NUREG-1150의 risk profile)
 - 기상 변동성 + 사고경위(L1+L2) 빈도의 불확실성
 - 도로망 GIS 정보를 활용한 network evacuation 모의 기능 구현



감사합니다.



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