CAES
Center for Advanced Energy Studies

A research partnership between Boise State University, Idaho National Laboratory, Idaho State University and University of Idaho.

Center for Advanced Energy Studies

SMR Cost Assessment for Input-Output Modeling

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Presentation to OECD/NEA Expert Workshop on Modeling Employment in the Nuclear Power Sector
OECD/NEA Headquarters, Issy-les-Moulineaux, France
February 13 – 14, 2014

epi Energy Policy Institute

❖ *CAES and the Energy Policy Institute*

Idaho National Laboratory (INL) has several research divisions, including:

- Center for Advanced Modeling and Simulation
- Institute for Nuclear Energy Science and Technology
- Advanced Test Reactor National Scientific Test Facility
- Center for Space Nuclear Research
- **Center for Advanced Energy Studies (CAES)**
  - Energy Policy Institute
    - Ongoing SMR initiative

CAMS Center for Advanced Modeling and Simulation

INEST Institute for Nuclear Energy Science and Technology

ATR National Scientific User Facility

Center for Space Nuclear Research

epi Energy Policy Institute

❖ *Overview of Presentation*

Introduction

- Overview of CAES SMR Research
  - Cost Estimation
  - Demand Forecast
  - Impacts Estimation

Ongoing Cost Estimation

- Code of Accounts
- Scaling Estimation

Ongoing IMPLAN Input-Output Analysis for SMRs

- Overview of IMPLAN Model
- Translating COA Expenditures into IMPLAN Sectors

❖ *Overview of CAES SMR Research*

Initial 2010 CAES Study

- Began ongoing research on the market potential and economic effects of developing a domestic SMR industry in the U.S.

Focus two-fold:

- Assess the market potential for SMRs under four different adoption scenarios
- Estimate the impacts on the U.S. economy from manufacture, construction, operation of SMRs in the U.S. through 2030

❖ *Initial 2010 CAES Study*

Market Assessment:

- Forecast future nuclear demand
  - Assumed electrical generation only
  - Included both domestic and international markets
- Data (from US Energy Information Agency, EPRI, IAEA) compiled into different nuclear adoption scenarios
  - Low, Moderate, High, Disruptive
- Moderate Deployment
  - Gradual growth in nuclear capacity additions and SMR captures 32% of nuclear capacity additions by 2030

❖ *Initial 2010 Study*

Estimation of economic impacts

- For each scenario, translated SMR share of added nuclear capacity into SMR units
  - Utilized generic 100 MWe SMR
  - National level study – no preferred manufacturing location or designs
- NOAK estimation
- Utilized cost estimates from public and vendor sources
  - Overnight costs for each SMR unit:
    - $500 million to manufacture and install on-site
  - Operations estimates for each SMR unit:
    - Midrange of vendor estimates ($0.075/kWh) at 90% capacity

❖ *Initial 2010 Study*

Estimation of economic impacts

- Traditional I-O industry studies utilize extant industrial sector
  - Not viable for SMR industry
- **Created SMR sector model consisting of manufacturing and construction sectors identified with nuclear**

Especially important for goal of "creating an industry cluster of interconnected companies and service providers around SMR technology"

❖ *Initial 2010 Study*

Estimation of economic impacts

- Created aggregated 21 sector model of SMR industry
  - Nine SMR manufacturing sectors
  - Four SMR construction sectors
  - One energy production sector

Other estimation features

- Economic data and multipliers in model from 2007 (pre-recession)
- Utilized constant dollars to avoid forecast of U.S. economy over 20 years

❖ *Initial 2010 Study*

- Aggregated Manufacturing Industry for SMRs

IMPLAN Sector	*IMPLAN Description*	*2007 NAICS*
125	All other basic inorganic chemical manufacturing	325188
133	Pharmaceutical preparation manufacturing	325412
186	Plate work and fabricated structural product manufacturing	33231
188	Power boiler and heat exchanger manufacturing	33241
189	Metal tank (heavy gauge) manufacturing	33242
198	Valve and fittings other than plumbing	332911-2, 332919
222	Turbine and turbine generator set units manufacturing	333611
255	Irradiation apparatus manufacturing	334517
256	Watch, clock, and other measuring and controlling device	334518-9
267	Motor and generator manufacturing	335312
369	Architectural, engineering, and related services	5413
375	Environmental and other technical consulting services	54162, 54169

❖ *Initial 2010 Study*

- Aggregated Construction Industry for SMRs

IMPLAN Sector	IMPLAN Description	2007 NAICS
34	Construction of new nonresidential commercial and health care structures	23*
35	Construction of new nonresidential manufacturing structures	23*
36	Construction of other new nonresidential structures	23*
39	Maintenance and repair construction of nonresidential maintenance and repair	23*

- Aggregated Energy Production Industry for SMRs

IMPLAN Sector	IMPLAN Description	2007 NAICS
31	Electric power generation, transmission, and distribution	2211

❖ *Initial 2010 Study*

Economic Impacts of a Typical SMR

	Sales	Value-Added	Earnings (Payroll)	Employment	Indirect Business Taxes
Manufacturing	$1,131,044,963	$540,660,687	$342,449,451	5,687	$30,722,980
Construction	$173,796,340	$86,517,571	$62,185,369	1,238	$5,030,832
Total SMR Production	$1,304,841,303	$627,178,258	$404,634,820	6,925	$35,753,812
Annual Operations	$107,109,777	$68,299,751	$27,732,333	374	$9,128,073
Total	**$1,411,951,080**	**$695,478,009**	**$432,367,152**	**7,299**	**$44,881,885**

❖ *Subsequent Improvement*

Focused on three dimensions

- **Develop more precise cost estimates**
  - Top-down and bottom-up estimations
- Improve and expand estimated economic impacts
  - Utilize cost estimates for each phase of design, engineering, licensing, manufacturing and installation
- Estimate cumulative impacts from deployment and operations over time

❖ *Subsequent Improvements*

Improved Cost Estimation

- Utilize 3-digit Code of Accounts (COAs) from EMWG
  - "*Cost Estimating Guidelines for Generation IV Nuclear Energy Systems, rev 4.2, 2007*
- Used major 3-digit COAs to provide overnight cost estimates
  - Top-down used cost model for Westinghouse PWR 12 (1,147 MWe) in 2011 ORNL report
  - Scaled each COA

    Full scaling (1/11.47), 'Half scaling' (1/5.735), No scaling (1), NA (0)

SMR Cost Estimation (3-Digit COA)

Structures and Improvements						
Number	General Description	Component	PWR12 BE Total Cost	Scaling Factor	SMR Estimated Cost	Notes
214	Security Building					
		Excavation work	0	1	0	Assume equivalent
		Substructure concrete	212731	1	212731	security needs
		Superstructure	2020104	1	2020104	
		Building services	1035857	1	1035857	
		Total	3268692		3268692	
218A	Control and Diesel Generator Building					
		Excavation work	0	0.174367916	0	
		Substructure concrete	1259825	0.174367916	219673.0602	
		Superstructure	29609078	0.174367916	5162873.235	
		Plumbing and drains	1845917	0.174367916	321868.701	
		Special HVAC	9118370	0.174367916	1589951.177	
		Lighting and service power	1603565	0.174367916	279610.2877	
		Total	43436755		7573976.46	
218 E	Emergency Feed Pump Structure					Passive ECCS design
		Excavation work	0	0	0	No emergency feed
		Substructure concrete	691,750	0	0	pump
		Superstructure	4,677,178	0	0	
		Plumbing and drains	294,706	0	0	
		Special HVAC	138,830	0	0	
		Lighting and service power	193,850	0	0	
		Total	5,996,314		0	

❖ *Current Research*

Improved Cost Estimation

- Comparison of estimated COAs to other studies for validation
  - 'Rolled up' 3-digit COAs to 2-digit COAs to compare to others

Account Number	Description	SMR Estimated Cost
21	Structures and improvements	97,148,812
22	Reactor plant equipment	112,863,131
23	Turbine plant equipment	93,647,442
24	Electric plant equipment	34,032,177
25	Miscellaneous plant equipment	19,094,604
26	Heat rejection system	20,497,701
Total Direct Costs		**377,283,867**
91	Construction Services	94960069.75
92	Engineering and Home Office Services	89028910.2
93	Field Supervision and Field Office Services	46619006.1
Total Indirect Costs		**230,607,986**
Total Overnight Cost		**607,891,853**

2-Digit COA Scaling Comparisons

Improved Cost Estimation

- 3-digit COAs rolled up into 2-digit COAs
- Comparison with estimated COAs from other studies on basis of costs and percentages of total costs

	ABWRs Rothwell (Col. 5)			Gen-4- System 80+			Rothwell SMR			PWR12		
	Original		Scaled to	Original		Scaled to	Original		Scaled to	Original		SMR Estimated
Account	$ millions	%	SMR ($)	$ millions	%	SMR ($)	$ 600 MW	%	SMR ($)	$ millions	%	Cost ($)
21	553	21.1%	81	499	27.1%	76.8	400	20.0%	66.7	482	22.2%	97
22	995	38.0%	145	515	28.0%	79.2	1,000	50.0%	166.7	727	33.5%	113
23	664	25.4%	97	489	26.5%	75.2	300	15.0%	50.0	537	24.7%	94
24	277	10.6%	40	142	7.7%	21.8	200	10.0%	33.3	195	9.0%	34
25 & 26	129	4.9%	19	197	10.7%	30.3	100	5.0%	16.7	230	10.6%	40
Total			382			283.4			333.3			378.0

❖ *Subsequent Improvements*

Improved Economic Impacts Estimation

- In initial study, utilized one option for I-O analysis:
  - Creation of aggregated industrial sectors representing SMR manufacturing, construction, and electricity production
- Another option is to use disaggregated model
  - Disaggregated IMPLAN model utilizes 440 industrial sectors
  - Industry specific multipliers for each sector
  - Estimates of expenditures in different activities/sectors
- 2-digit COAs allocated to IMPLAN sectors shown on next slide

❖ *Subsequent Improvements*

Improved Economic Impacts Estimation

Account	IMPLAN	Hypotetical Industrial Classification	Description	SMR Cost
21	35	Construction of new nonresidential manufacturing structures	Structures and improvements	$ 97,148,812
22	188	Power boiler and heat exchanger manufacturing	Reactor plant equipment	$ 112,863,131
23	222	Turbine and turbine generator set units manufacturing	Turbine plant equipment	$ 93,647,442
24	267	Motor and generator manufacturing	Electric plant equipment	$ 34,032,177
25	186	Plate work and fabricated structural product manufacturing	Miscellaneous plant equipment	$ 19,094,604
26	188	Power boiler and heat exchanger manufacturing	Heat rejection system	$ 20,497,701
Total Direct Costs				**$ 377,283,867**
91	369	Architectural, engineering, and related services	Construction Services	$ 94,960,070
92	375	Environmental and other technical consulting services	Engineering and Home Office Services	$ 89,028,910
93	35	Construction of new nonresidential manufacturing structures	Field Supervision and Field Office Services	$ 46,619,006
Total Indirect Costs				**$ 230,607,986**
Total Overnight Cost				**$ 607,891,853**

❖ *Subsequent Improvements*

Improved Economic Impacts Estimation

N-Kind: Economic Impacts of a Typical SMR Module					
	Sales	**Value-Added**	**Earnings (Payroll)**	**Employment**	**Indirect Business Taxes**
Manufacturing	$1,135,744,458	$610,371,869	$393,450,747	6,792	$32,042,119
Construction	$519,451,142	$274,259,684	$182,484,398	3,618	$15,201,434
Total SMR Production	**$1,655,195,600**	**$884,631,553**	**$575,935,145**	**10,410**	**$47,243,553**
Annual Operations	**$101,566,466**	**$76,471,996**	**$26,586,992**	**356**	**$13,100,859**
Total	**$1,756,762,066**	**$961,103,549**	**$602,522,138**	**10,767**	**$60,344,412**

❖ *Subsequent Improvements*

Improved Economic Impacts Estimation

- Estimated economic impacts significantly larger
  - Cost estimates higher by approximately 22%
    - » $607.9 million versus $500 million
  - Impacts higher by approximately 26%
- Use of more detailed cost estimates allocated to larger number of sectors in the disaggregated model

❖ *Subsequent Improvements*

Continuing Work on More Detailed COA Estimation

- Detailed analysis and scaling of all COAs for 1,147 MWe PWR 12 used in 2011 ORNL report

- **Scaling Process**

1) PWR12 BE Code of Accounts (ORNL AHTR report)

2) Scaled PWR12 BE COA numbers using EEDB derived scaling factors - scaling made at 3-digit level

3) Adjusted Account 22 to compensate for cost savings from design simplification (Carelli et al., 2010). Adjustment made at 2-digit level (17% cost reduction)

4) Adjusted accounts 22-26 for factory production productivity gains made via learning (EPIC, 2011). Adjustment made at 2-digit level (19% cost reduction)

5) Adjusted accounts 91-93 to reduce supervisory expenses to accommodate for factory production assembly of most components. (Zhang, 2007). Adjustment made at 2-digit level (20% cost reduction)

❖ *Subsequent Improvements*

Continuing Work on More Detailed COA Estimation

- **Link to COA spreadsheet**

❖ *Subsequent Improvements*

Future Work

- With the improvement of the COAs and greater sectorial detail, reevaluate the IMPLAN/NAICAS mapping to the COAs
- Explore custom built IMPLAN production functions
  - Custom build SMR production functions in IMPLAN and/or *Analysis-By-Parts*
  - Download IMPLAN data in Excel or other software and create custom production functions

❖ *Thank You*

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