NuScale Energy Supply for Oil Recovery and Refining Applications

D. T. Ingersoll,[a] C. Colbert,[a] R. Bromm,[b] and Z. Houghton[a]
[a]*NuScale Power, LLC*
1100 NE Circle Blvd, Suite 200, Corvallis, OR 97330
[b]*Fluor Corporation*
100 Fluor Daniel Dr., Greenville, SC 29607
Tel: 541-360-0585 , Email: dingersoll@nuscalepower.com

Abstract – *The oil recovery and refining market is highly energy intensive, representing roughly 7% of the total U.S. energy consumption. The NuScale small modular reactor design is especially well suited for supplying clean, reliable energy to this market due to the compact size of the reactor and the high degree of modularity included in the design, allowing multiple reactors to be combined into a scalable central plant. A preliminary technical and economic assessment has been completed to evaluate the feasibility and desirability of using NuScale power modules to support oil recovery and refining processes, thus reducing the overall carbon footprint of these industrial complexes and preserving valuable fossil resources as feedstock for higher value products.*

I. INTRODUCTION

The production of refined petroleum products is highly energy intensive with most of the energy being used either in the field for crude oil recovery processes or at a refinery for processing of the crude oil into end-use products such as transportation fuels or petrochemicals. Additionally, a type of refinery called an “upgrader” may be constructed near large fields of low quality deposits such as tar sands to provide initial processing of the crude oil before distribution to a polishing refinery. Over the past decade, roughly 7% of the total U.S. energy consumption is by oil refineries, which represents roughly 1800 TWhr (6,140 TBtu) annually, or an average power demand of 200 GWt. Older refineries can consume up to 15-20% of the energy value of their feedstock for supplying process heat,[1] although modern refineries average closer to 6% and use almost entirely natural gas feedstock or refinery fuel gas to produce the required heat.[2] Depending on the actual process, energy may be needed in the form of steam, electricity or direct fired heat as discussed below.

The energy demands in the field and at the refinery are quite different and have different implications on the types of energy sources used for these applications. Nuclear energy may represent an attractive technology because of its abundant, reliable and clean energy characteristics. Although the traditional large nuclear plant designs may be suitable for some of the largest oil refineries, a new generation of smaller sized nuclear plant designs appears to be a better match. These designs, often referred to as small modular reactors (SMR), are generally characterized by having unit power outputs of less than 300 MWe and are substantially manufactured in a factory and installed at the site rather than constructed on-site.

A new SMR design that has been under development in the United States since 2000 is the NuScale design that is being commercialized by NuScale Power with the strong financial backing of Fluor Corporation. The highly robust and scalable nature of the NuScale plant design, which is based on well-established light-water reactor (LWR) technology, creates a unique solution to provide affordable, clean and abundant energy to the oil industry in the near-term with the opportunity to maximize conversion of valuable petroleum feedstock for the desired end products. Also, the emissions-free nature of the nuclear plant can reduce the overall greenhouse gas (GHG) footprint of the oil recovery and refining processes and provide a hedge against existing air quality standards, expansion restrictions in non-attainment areas, and potential GHG emission policies and pricing surcharges.

II. NUSCALE DESIGN OVERVIEW

The NuScale SMR plant is an innovative design that builds on 60 years of world-wide experience with the commercial application of pressurized LWR technology. The design incorporates several features that reduce complexity, improve safety, enhance operability, and reduce costs. From the outset, the top level design goals for the NuScale plant have been to achieve a high level of safety and asset protection while providing an affordable approach to nuclear power that gives the plant owner the maximum flexibility in construction, operation and application of the plant.

The fundamental building block of the NuScale plant is the NuScale power module. The power module consists of a small 160 MWt reactor core housed with other primary system components in an integral reactor pressure vessel and surrounded by a steel containment vessel, which is immersed in a large pool of water. Several power modules—as many as 12 modules—are co-located in the same pool to comprise a single plant.

A diagram of the NuScale power module is shown in Fig. 1. The reactor vessel is approximately 20.0 m (65 ft) tall and 2.7 m (9 ft) in diameter. The integral vessel contains the nuclear core consisting of 37 fuel assemblies and 16 control rod clusters. The fuel assemblies contain a 17 by 17 array of zircalloy-clad, low-enriched UO_2 fuel similar to traditional pressurized LWRs. Above the core is a central hot riser tube, a helical coil steam generator surrounding the hot riser tube, and a pressurizer. The helical coil steam generator consists of two independent sets of tube bundles with separate feedwater inlet and steam outlet lines.

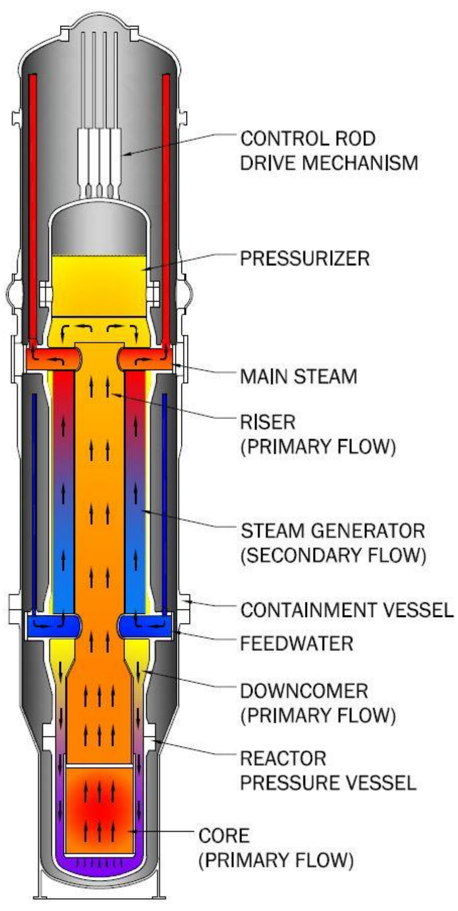

Fig. 1. Schematic of a NuScale power module.

Primary reactor coolant is circulated upward through the reactor core and the heated water is transported upward through the hot riser tube. The coolant flow is turned downward at the pressurizer plate and flows over the shell side of the steam generator, where it is cooled by conduction of heat to the secondary coolant and continues to flow downward until its direction is again reversed at the lower reactor vessel head and turned upward back into the core. The coolant circulation is maintained entirely by natural buoyancy forces of the lower density heated water exiting the reactor core and the higher density cooled water exiting the steam generator. On the secondary side, feedwater is pumped into the tubes where it boils to generate superheated steam, which is circulated to a dedicated turbine-generator system. Low pressure steam exiting the turbine is condensed and recirculated to the feedwater system.

The entire nuclear steam supply system is enclosed in a steel containment that is 24.6 m (80 ft) tall and 4.6 m (15 ft) in diameter. The small volume, high design pressure containment vessel is a unique feature of the NuScale design and contributes significantly to the large safety margins and overall resilience of the plant design. Multiple modules are placed in a single large pool contained within an aircraft-resistant reactor building. A cut-away view of a twelve-module reactor plant is shown in Fig. 2.

As can be seen in Fig. 2, the NuScale module is located below grade in a pool of water. The reactor pool provides passive containment cooling and decay heat removal. Specifically, the pool provides an assured heat sink with a capacity to absorb all the decay heat produced by up to 12 fully mature cores for greater than 30 days, after which air cooling of the vessel is sufficient to avoid fuel damage. The pool also helps to reduce and delay fission product releases in the unlikely event of fuel failure and provides radiation shielding outside containment to reduce operational exposure. Finally, the below grade pool provides enhanced physical security by adding additional challenges to fuel access.

There are several key features of the NuScale plant that collectively distinguish it from the many other SMRs being developed today and make it especially well-suited for application to the oil industry.

- *Compact size.* The nuclear steam supply system can be entirely prefabricated off site and shipped by rail, truck or barge. This reduces construction time due to parallel fabrication considerations and reduces overall schedule uncertainty due to the reduced amount of on-site construction activities.
- *Natural circulation cooling.* Natural circulation operation eliminates pumps, pipes, and valves and hence the maintenance and potential failures associated with those components while also reducing house loads.

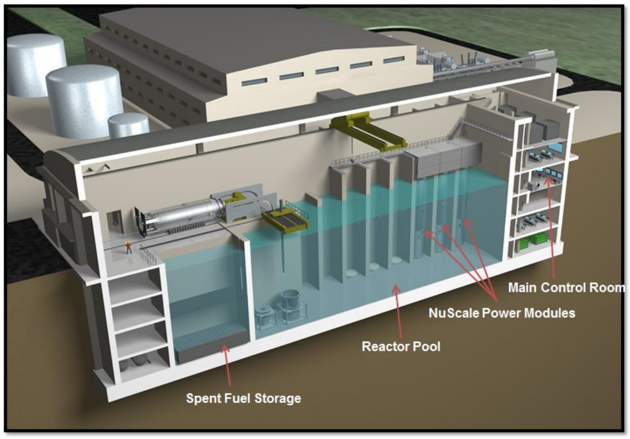

Fig. 2. Cut-away view of reactor building for 12-module NuScale plant.

- *Light water reactor technology.* The NuScale plant can be licensed within the existing LWR regulatory framework, thus drawing on a vast body of operational data, proven codes and methods, and existing regulatory standards. This will facilitate expeditious licensing of the plant and reduce uncertainties in the plant's performance.
- *Nuclear modularity.* While most new nuclear builds utilize modular construction practices, the NuScale design extends this approach to the nuclear steam supply system. Each power module is contained within a compact, factory-manufactured containment vessel and provides output steam to a dedicated and independent power conversion system. The scalability of the plant from 1 to 12 modules further enhances plant economics and deployment flexibility.
- *Dedicated power trains.* Because each power module, including the power conversion system, is independent of other modules, it is possible to operate the plant in such a manner that some modules produce only electricity while other modules produce only steam for thermal heat applications. This feature allows for flexible tailoring of the plant output to match customer needs.

The synergy created by these unique features, especially plant simplicity, reliance on existing light water technology, and the plant-level flexibilities afforded by the multi-module configuration, all combine to position the NuScale plant for early and successful application to industrial heat applications.

III. OIL RECOVERY APPLICATIONS

A major energy consumer in the petroleum industry is the oil recovery process. Most of the easily accessible crude oil has already been depleted and oil companies are utilizing energy-intensive processes to increase oil recovery from existing fields, extraction from new formations such as tar sands, or extraction from non-traditional sources such as oil shale. In the case of enhanced recovery from traditional formations or tar sands, 90% of the energy usage is steam, which is used in a process called "steam assisted gravity drain" (SAGD). As shown in Fig. 3, the steam is injected *in situ* to reduce the viscosity of the oil, which can then be pumped out using conventional methods. The steam quality is generally quite low (60%) and dirty.

In the case of oil shale, the oil is actually contained in the sedimentary rock as kerogen, which is converted to light oil and other products by slow heating.[3] The heating can be either *in situ* as part of underground heating operations or *ex situ* as part of the mining operation and trucked to a central facility for heating and oil extraction.

A co-generation option for the heat source is generally preferred due to the need for a modest amount of electricity for pumping operations and general housekeeping functions.[4] Reliability of the heat source is important but not as critical as for refinery applications, as discussed in the next section. Long disruptions in the heat-up process would become expensive if the rock formations are allowed to cool down significantly. Temperature requirements for enhanced oil recovery processes generally range from 250-350°C, which is achievable with an LWR such as NuScale if heat recuperation or temperature boosting is used.

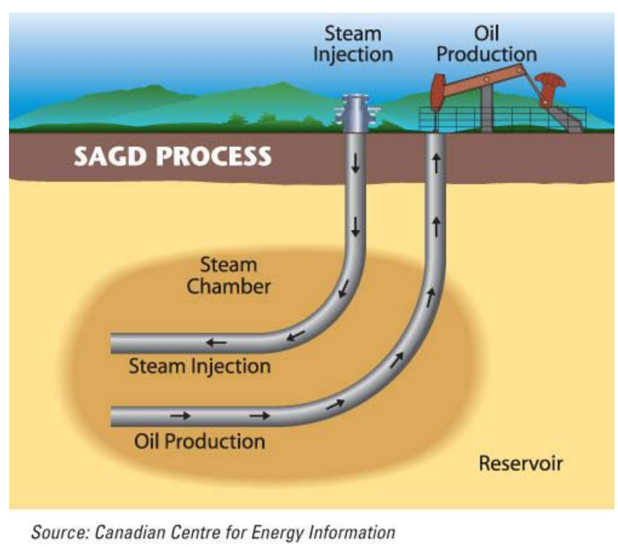

Fig. 3. Diagram of steam-assisted gravity drain process for crude oil recovery.

The small module size and scalability of the NuScale plant provides unique opportunities for advanced oil recovery processes. In this case, however, challenges may be dominated by economic and logistical considerations. First, unlike the refinery application in which a centralized multi-module plant could provide the necessary electricity and steam for the entire refinery, the oil recovery application requires a more geographically distributed array of smaller energy sources. This might dictate that the modules be deployed as single or few-module clusters, which could dramatically increase the cost of construction, operations, security, etc. Several of these challenges are discussed in Ref. 3.

The other logistical consideration for *in situ* oil recovery is the longevity of the field operations in relation to the anticipated NuScale plant lifetime. Using enhanced recovery processes to extract heavy oil or oil from tar sands is likely to fully deplete a given field in 10 to 15 years. This depletion time may lengthen some with the widespread use of horizontal drilling that can significantly extend the reach of a well. Even so, the demand for a heat source at a fixed location is likely to be significantly shorter than the 60-yr lifetime of a nuclear facility. Currently, oil companies use mobile natural gas units to provide the energy. Comparable nuclear options might include the development of a mobile nuclear plant or a less enduring plant with a 10-20 year design lifetime. These options have their own set of challenges and are long-term solutions at best. In the case of oil shale, there are indications that the deposits are sufficiently massive and the heating process sufficiently protracted that harvesting the oil from these formations may require many tens of years, and hence be a better match for a nuclear plant with a traditional design life.

Although these economic and logistical considerations cause a nuclear option for *in situ* oil recovery to be less obvious, *ex situ* recovery, i.e. the shale oil is mined and processed elsewhere, is a potential application that overcomes the distributed and migratory issues of *in situ* recovery. Furthermore, oil recovered from tar sands is of sufficiently low quality that it requires processing in upgrader facilities located near the oil fields. Upgraders are basically in-field refineries that can service a large oil recovery area. As the local recovery operations migrate to new areas of the larger field, the oil is piped over progressively longer runs to the upgrader. The upgrader has a much longer lifetime and energy demand characteristics similar to finishing refineries. Therefore the NuScale suitability arguments for refineries that are discussed in the next section apply equally well to upgraders.

IV. OIL REFINERY APPLICATIONS

The energy requirements of a refinery represent a more practical and potential application of a NuScale plant. Refineries are large, energy-intensive industrial complexes with extended lifetimes similar to nuclear power plants. Although the initial design lifetime of a refinery may be 20 years, they are frequently upgraded as technology improves or product markets evolve and typically operate for several decades. One of the longest running refineries in the U.S. is the Casper Refinery near Rawlins, Wyoming, and has been operating for 90 years. Also, many refineries are in less populous areas and have industrial exclusion zones. In 2007, there were 145 U.S. refineries with the average refinery using roughly 650 MWt, which is distributed as 8% steam, 17% electricity, and 75% heat.[5] Some of the largest refineries can use in excess of 2000 MWt. Table 1 provides a summary of common refinery processes and the required temperatures (Ref. 5).

TABLE 1
Primary oil refining processes and required temperatures
(Table 2-3 from Ref. 5)

Process	Description	Sub-categories	Process Temp (°C)
Distillation	Separation of crude oil into hydrocarbon groups based on molecular size and boiling points	Atmospheric	400
		Vacuum	400-500
Thermal Cracking	Use of heat and pressure to breakdown, rearrange, and combine hydrocarbons	Delayed Coking	500
		Flexi-coking	500-950
		Fluid Coking	500-550
		Visbreaking	400-500
Catalytic Cracking	Breaking heavier complex hydrocarbons into lighter molecules		480-815
Catalytic Hydro Cracking	Use of hydrogen and catalysts on mid-boiling point hydro- carbons		290-400
Hydro Treating	Treatment of petroleum in the presence of catalysis and hydrogen		< 427
Catalytic Reforming	Conversion of low-octane napthas into high-octane gasoline blending components		500-525

The small module size and modular nature of the NuScale plant is well suited for this application. A multi-module, multi-output plant can be easily customized to the needs of a specific refinery while maintaining a highly standardized nuclear power module design. A single NuScale power module produces roughly 245,000 kg/hr steam with an outlet temperature of approximately 300°C. Since superheated steam has limited use for process heating, a secondary heat transport medium would be used such as high pressure water or a specially designed heat transfer fluid such as DOWTHERM™. An intermediate heat exchanger transfers heat to the secondary fluid stream for use in pre-heating refinery process inputs and provides additional isolation between the reactor and refinery. The end-use heated fluid characteristics can be adjusted as needed to match the requirements of a specific process. An initial estimate is that a single 160 MWt module can provide for pre-heating of several refinery process input streams to 288°C (550°F). A schematic of a potential coupling between a NuScale module and an oil refinery is given in Fig. 4. An economic assessment for this type of coupled operation is discussed in Section V for a representative refinery.

Another attractive feature of the NuScale plant design for this application is the staggered refueling of modules. The plant is designed with a high level of independence between modules, including the power conversion systems, so that other modules can continue to produce power (or steam) while one of the modules is off-line for refueling. Many refinery processes become very inefficient if disrupted and therefore have a high reliability requirement. A multi-module NuScale plant uniquely provides for redundancy and availability of energy supply.

As indicated in Table 1, the output of a NuScale module is in the lower range of process temperature requirements. A variety of hybrid cycles have been suggested in the literature that could be used to boost the end-use steam temperature. Candidate approaches are to use electrical heaters powered by an electricity-generating module or a natural gas fired heater. Although some feedstock is consumed for energy generation in the latter case, feedstock usage is much less than if used to achieve the full steam temperature. Although advanced high-temperature reactors appear capable of reaching the required temperatures directly, an LWR-based nuclear system can be available in the near-term and provide a high level of confidence in deployment and operational reliability.

In addition to the liquid fuels produced in a refinery, there are many oil-derived petrochemical products that can be processed at temperatures within the range of a NuScale plant. A list of these products is given in Table 2 (extracted from Table 2-6 in Ref. 5). Depending on the rise and fall of demand for liquid fuels, many refineries can shift to petrochemical production to maintain refinery capacity.

Challenges for the viability of using a NuScale plant to provide process energy at a refinery are primarily regulatory—both for the nuclear plant and the refinery. The potential impact of an accident at either plant on the other plant will need to be carefully analyzed. The low risk factor and high level of robustness in the NuScale design, which results from many best-in-class plant design features, will help to reduce the regulatory and social-political hurdles for placing a nuclear facility near a refinery.

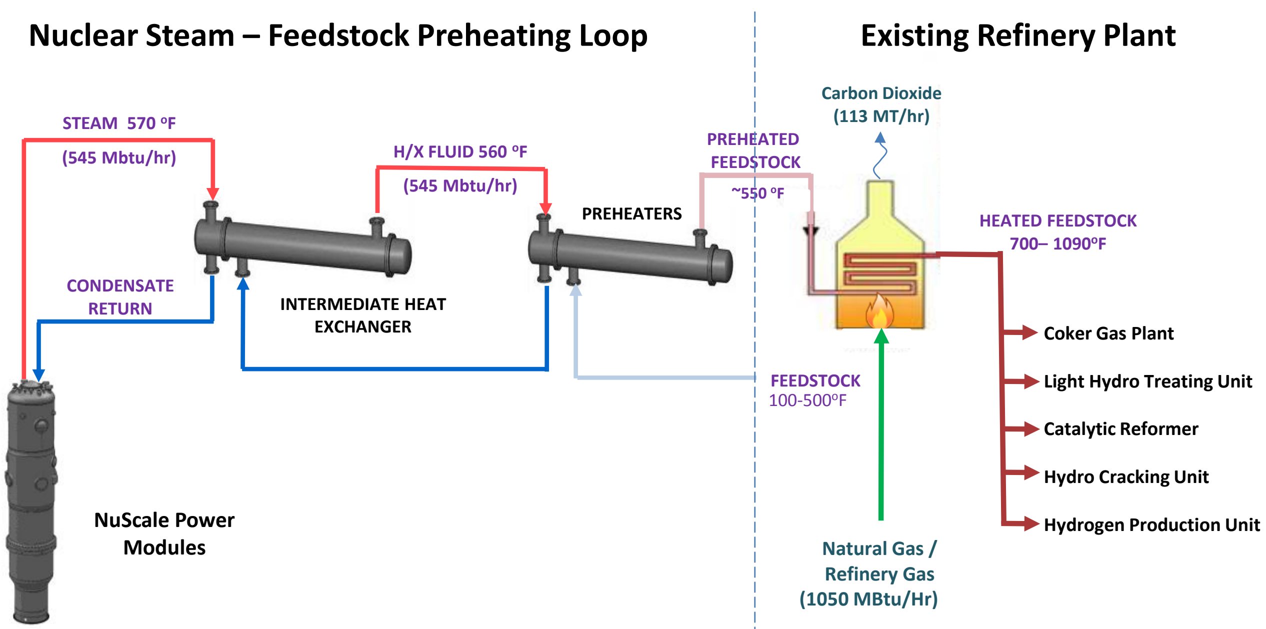

Fig. 4. Simplified arrangement for coupling a NuScale plant to an oil refinery for feedstock preheat.

TABLE 2
Process temperatures and annual U.S. production rates of various petrochemicals (Excepts from Table 2-6 of Ref. 5)

Chemical	Process	Process Temp (°C)	2002 Production (billion lb)
Ethylbenzene	Friedel-Crafts Alkylation	90-420	13.6
Ethylene Oxide	Air Epoxidation	270-290	9.2
Acetic Acid	Multiple	50-250	6.7
Cumene	Friedel-Crafts Alkylation	175-225	7.3
Cyclohexane	Transformation of Benzene	210	3.0
Terephthalic Acid	Amoco Process	200	9.1
Vinyl Acetate	Vapor-phase Reaction	175-200	2.8
Ethylene Glycol	Hydration and Ring Opening	50-195	7.5
Butyraldehde	Oxo Process	130-175	3.1
Adipic Acid	Air Oxidation	50-160	2.2
Bisphenol A	Phenol with Acetone	50	2.3
Ethylene Dichloride		40-50	23.8
Phenol	Rearrangement of Cumene Hydroperoxide	30	5.2
Urea		190	18.5
Soda Ash		175	
Ammonium Nitrate	Vacuum Evaporation	125-140	17.2
Aluminum Sulfate		105-110	2.2
Phosphoric Acid	Wet process	75-80	26.8
Nylon 6 and Nylon 6.6	Electrolysis of Brine	280-300	2.6
Polyester		200-290	3.9

V. ECONOMIC ASSESSMENT

To understand the economic viability of supporting a refinery with a NuScale plant, a typical large-size refinery was selected capable of processing 250,000 barrels/day of crude oil to produce diesel fuel, gasoline, petroleum coke and other petroleum products. Anticipated energy demands for this scale of refinery are listed in Table 3. Six NuScale modules are sufficient to provide the required 250 MWe of electricity for the refinery, as well as the house load for the NuScale plant.

To determine how many modules are needed to meet the non-electrical energy demands requires a better understanding of the detailed process flow characteristics of the refinery. For example, although steam output from NuScale modules could be used to replace the refinery fuel gas (RFG) for some of the fired heaters, the RFG is a by-product of refinery processes and it is more cost-effective to consume it internally than to process it further for external use. Also, the use of natural gas (NG) in a methane reforming process appears to be the most efficient process for hydrogen production. However, the technical and economic suitability of using a NuScale plant to produce hydrogen through a high-temperature steam electrolysis method is being evaluated and may result in additional NG replacement potential. Of the 1,800 MBtu/hr energy demand listed for NG-supplied fired heaters, it appears that NuScale-supplied steam can provide approximately 1,660 MBtu/hr. This requires four NuScale modules in addition to the six modules needed to supply the electrical demand. Hence, with these assumptions, a 10-module NuScale plant can meet the selected energy needs indicated in Table 3.

TABLE 3
Primary energy demands for typical refinery producing 250,000 barrels per day

Traditional Energy Source	Energy Demand (MBtu/hr)	Replaceable by NuScale Module
Natural Gas		
• For 250 MW of electricity	1,900	1,900
• For H_2 production	4,100	No
• For fired heaters	1,800	1,660
• For pilot lights	140	No
Refinery Fuel Gas		
• For fired heaters	2,000	No

Table 4 summarizes the economic assessment of a 10-module NuScale plant coupled to the refinery, assuming that the NuScale plant replaces the 250 MW electricity demand and 1660 MBtu/hr of NG consumption for fired heaters. The capital cost for the refinery assumes a typical 250 MWe gas-turbine combined cycle plant is used to produce electricity from the NG. The estimated NuScale capital cost is for an nth-of-a-kind 10-module plant. The estimated operating cost for the NuScale plant includes annual operations and maintenance costs, nuclear waste fee, and decommissioning fund contributions. The fuel cost for the NuScale plant is assumed to be fixed at \$48.2 million/yr, while the NG cost is treated as a variable. Based on these assumptions, Fig. 5 shows the potential annual operating cost savings as a function of the cost of NG with four different fees levied on CO_2 emissions. The higher operating cost of the NuScale plant is quickly mitigated by increasing the cost of NG over \$5/MBtu or by adding a surcharge based on CO_2 emissions.

TABLE 4
Key economic parameters for 10-module NuScale plant coupled to 250,000 bbl/d refinery

	Fossil Heat	With NuScale	Savings
NG Consumption (MBtu/hr)	7,960	4,366	3,594
CO_2 Production (MT/hr)	525	336	189
Capital Cost (million)	\$ 290	\$ 2,100	(\$ 1,810)
Owner's Cost (million)	\$ 70	\$ 310	(\$ 240)
Annual Operating Cost* (million)	\$ 6.8	\$ 104.6	(\$ 97.8)
Annual Fuel Cost (million)	Variable (subject to NG unit cost)	\$ 48.2	Variable (NG cost less \$48.2)

*Does not include financing fees, taxes or fuel costs

The other economic consideration is the capital cost of the nuclear facility. Figures 6 and 7 show the potential payback periods as a function of NG fuel cost for \$0/MT and \$40/MT of CO_2 emission. Comparing Fig.s 6 and 7, it is apparent that there is only a modest correlation of payback period with CO_2 emission cost, lowering the 25-yr payback cost of NG only from \$9.5/MBtu to \$7.5/MBtu when imposing a \$40/MT CO_2 penalty.

This simplified economic assessment is based on conservative assumptions, including: (1) the module balance-of-plant equipment for steam/heat-producing modules have the same cost (capital and O&M) as an electricity-producing module, i.e. the total plant cost is the same regardless of individual module product, and (2) no credit is assumed for utilizing waste heat rejected by the electricity-producing modules (roughly 100 MWt per module) to augment the output of the steam-producing modules.

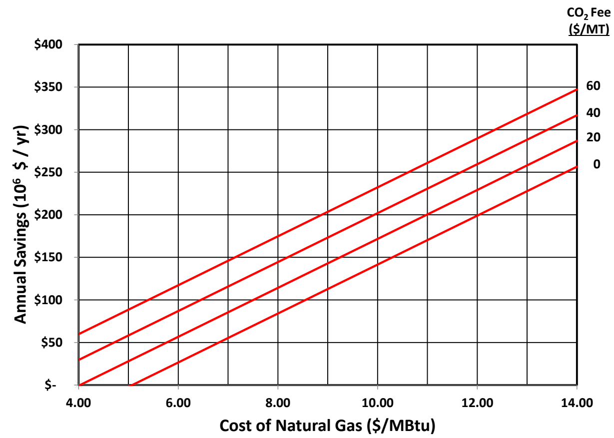

Fig. 5. Potential savings in annual operating cost (including fuel cost) with coupled NuScale-refinery plant.

More rigorous analyses and optimization of the NuScale plant design for non-electrical applications will improve the overall economics. In addition, other externalities could further improve NuScale's economic competitiveness, especially regarding the potential impact of future policies (and resulting costs) regarding air quality standards and GHG emissions. Although there is no certainty associated with how much and when the policies will impact GHG-emitting sources in the U.S, many countries already enact emission penalties. Also, existing air quality regulations imposed by the Environmental Protection Agency severely limit industrial expansion in non-attainment areas, i.e. locations where air quality is already below mandated standards. California, which often leads the country in environmental restrictions, already restricts the use of high-emission products and is increasingly concerned over the full life-cycle carbon and criteria pollutant (SOx, NOx, CO, PM10) footprint of products. As a consequence of the 2006-enacted Global Warming Solutions Act (Assembly Bill 32), they will not allow crude oil from Canada to be imported to CA refineries because of the "dirty" processing used to acquire the crude.[2]

Based on a simple analysis, the NuScale economics look viable for supporting large refinery applications, even in the absence of emission penalties. This is particularly true in countries or regions of the US where low-cost natural gas is not available. Given regional differences in energy costs, a more refined study may identify domestic and international locations with more favorable economics.

Also, given the uncertainties in emission penalties, it may be possible to develop a long-term power (and steam) purchase agreement structure that is mutually attractive to NuScale and the oil companies, thus allowing them to hedge against future emission restrictions and costs.

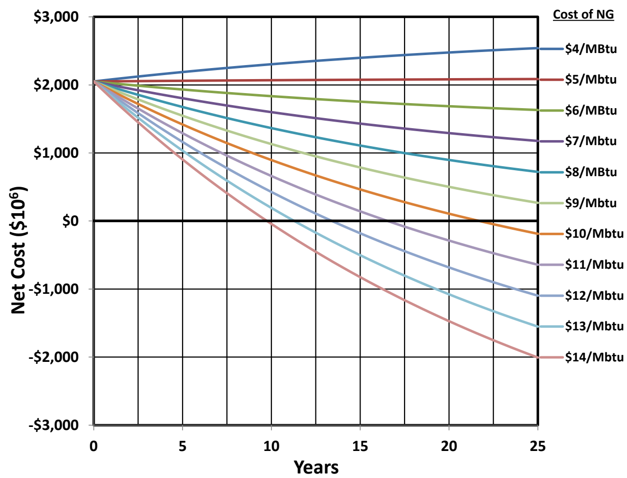

Fig. 6. Potential capital pay-back period for the case of no CO_2 emmision penalty.

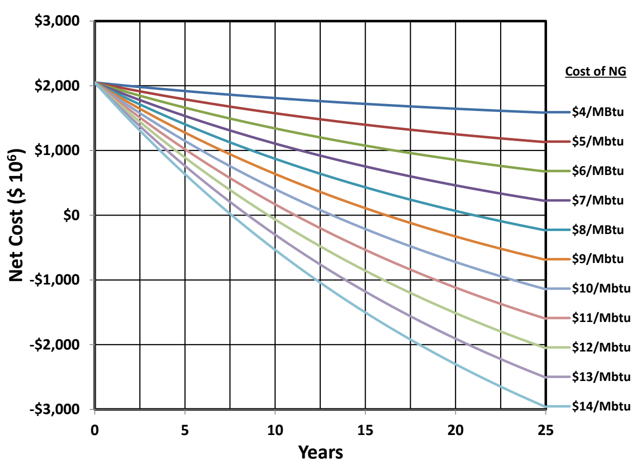

Fig. 7. Potential capital pay-back period for the case of a $40/MT CO_2 emmision penalty.

IV. CONCLUSIONS

A preliminary technical evaluation has been completed for assessing the potential application of the NuScale SMR to the substantial energy demands of the oil industry. Both oil recovery and oil refining applications were considered. In the case of oil recovery processes, the small unit size, flexible plant design and enhanced safety features of the NuScale design make it potentially attractive for distributed energy delivery, subject to overcoming some identified logistical challenges. The same design features make the NuScale design especially well-suited for application to oil refineries and upgraders, thus reducing the overall GHG footprint of the refinery and allowing the fossil-based feedstocks to be preserved for conversion to high-value fuels.

An economic assessment was performed for the case of a representative refinery sized to process 250,000 barrels/day of crude oil. The cost differential between using nuclear-generated electricity and heat relative to the reference scenario of using natural gas was calculated for a variety of natural gas prices and potential CO_2 tax penalties. The analysis showed that based only on operating costs, the 10-module NuScale plant is competitive with the reference case for natural gas prices as low as $5/MBtu, even with no CO_2 tax. The capital investment for the NuScale plant can be recovered in 25 years if the natural gas cost exceeds $9.5/MBtu without a carbon tax, or $7.5/MBtu with a $40/MT CO_2 penalty. While such gas prices exceed current prices in the U.S., they are well below prices in many other countries.

REFERENCES

1. C. W. Forsberg, "Sustainability by combining nuclear fossil, and renewable energy sources," *Progress in Nuclear Energy*, **51**, 192-200 (2009)

2. A. Smith, Fluor Corporation, private communication (2013).

3. D. Curtis and C. W. Forsberg, "Light-Water-Reactor Arrays for Production of Shale Oil and Variable Electricity," *ANS Transactions*, **108**, (2013).

4. *Advanced Applications of Water Cooled Nuclear Power Plants*, International Atomic Energy Agency, TECDCC-1584 (2007).

5. J. Konefal and D. Rackiewicz, "Survey of HTGR Process Energy Applications," MPR-3181 (May 2008).