Torrefaction: A Renewable Power Enabler for Michigan

Comments for submission to Michigan's Energy Future

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Summary

Increasing the Michigan RPS beyond 10% by 2015 depends to a large extent upon availability of cost-effective choices to large Michigan utilities. While biomass, landfill gas, solar, hydro and geothermal are modest contributors, wind power has been the technology of choice by the two major utilities to achieve PA295, and wind would certainly be a significant part of a plan to increase renewable power further. But the current implementation of wind power to move renewable power from 3% to 10% over 7 years of the current RPS is being accomplished by populating the highest wind zones in the state. This may be keeping pace with the current electric power growth of about 1% per year, but it will likely have little impact on coal burning, and therefore cause no significant reduction in Michigan CO2 footprint.

A stable, sustainable plan for renewable power must include consideration of future climate change actions, which will likely force reductions in fossil CO2 emissions. A reduction of net fossil CO2 emissions by 25% from 2000, either by reduced fossil fuel burning or by CO2 capture and storage, achieved by 2030, might be a starting point for planning while discussion continues. Achieving this with renewable power will be a challenge but is within reach. However, expecting wind to be the primary path has considerable risk because the best locations are taken first, so that further locations will have decreasing capacity factor even as technology improves; offshore sites are expensive to build and will likely bring public resistance; infrastructure investment and gas turbine backup is necessary in order to retire coal baseload; natural gas backup will have limited lifetime if fossil CO2 is constrained in the future; and at some point federal incentives will be dropped.

Even with equal biomass allotted to liquid biofuels, Michigan has sufficient sustainable biomass to support 20% of electricity needs, which is well over 30% of coal consumption, but implementation is well below this potential. While direct burning of wood chips is growing in Michigan, most applications are full plant conversions with ratings below 50 MW. Co-firing in existing coal plants is generally limited to about 10% and incurs incremental costs because of differences in storing, handling and combustion. Large coal plants have been discouraged from co-firing biomass due to uncertain quantity and quality of current biomass supply, reduction in rating, and possible maintenance risks. Plant size has been limited by gathering distance due to transportation cost; with half the energy content of western coal, twice the mass of wood chips must be moved, typically by covered truck. But the current demand and supply does not necessarily indicate what future demand with managed supply and pretreatment could become.

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Thermal treatment of biomass provides a path to achieve this reduction in fossil CO2 within this timeframe at reasonable cost to Michigan residents and in support of Michigan businesses and employment. Torrefaction, a mild pyrolysis process, decomposes the tough fibers in wood, reduces weight by 30% while retaining as much as 90% of the energy. When densified into pellets or briquettes, it has properties similar to western coal, and can be used in existing coal plants with existing storage, handling, grinding and combustion. Slagging and corrosion concerns can be avoided by sourcing wood instead of energy grasses or crop residuals. High energy density and water rejection properties allow transportation by rail or ship, so delivery can be from increased resource distance, which removes the constraint on plant size. Modest facility cost and complexity allows torrefaction reactors to be located at processing centers near the wood supply with access to rail or ship. Co-firing trials of 20% and higher are being conducted successfully in large coal plants in Europe, and are planned in the US as the supply becomes available. Torrefaction facilities are being commissioned in the US to supply contracts with European plants that are facing fossil CO2 constraints and renewable energy requirements. The feasibility study of torrefied wood chips conducted by the Lansing Board of Water and Light, supported by the Michigan Biomass Energy Program (LBWL, 2010), found acceptable co-fired combustion, but concluded that pellets would be preferred for handling by coal equipment. Torrefaction involves wood handling and heat treatment equipment that can be provided by Michigan industry, and is supported by active research and development at MSU and MTU. Sourcing Michigan biomass retains a portion of the cost of imported fossil fuels to be invested in sustainable Michigan businesses and jobs. While the cost of biomass is higher than current western coal or natural gas on a unit energy basis, cost comparison with future coal, natural gas or wind should be done without subsidy at equal CO2 constraint and with equal sustainable, dispatchable megawatt hours, with consideration of economic benefit to Michigan. Equalized cost is expected to be competitive.

Torrefied wood pellets to co-fire with coal provides a technology path for Michigan that, in combination with other renewable pathways, enables renewable power of 25-30% by 2030. Resources and implementation technology can support this path. Existing coal plants, including the full range of plant sizes, will be able to migrate toward renewable energy without facility change or capital cost at the plant. Existing plants can continue to operate toward planned useful life, rather than be terminated prematurely. Selecting a long-term renewable energy plan will prepare Michigan for eventual climate change regulations and will encourage the development of Michigan-based businesses over a time frame to avoid disruption.

Recommendations

- Define a renewable power schedule of at least 20 years, with a check point at 10 years, and consistent with possible climate change requirements. Total renewable power of 20% by 2025 and 30% by 2035 is suggested. These fractions could be higher if the requirement is defined as non-fossil and incremental nuclear power is included.
- Encourage the development of biomass energy supply via public awareness of the value of active forest management and energy plantations. Demonstrate sustainable bioenergy best practices in state forests and on state land.
- Conduct all economic comparisons without federal or state incentives, and futured to 2020 and beyond with equal impact on fossil CO2 emissions. Include economic impact on Michigan businesses and jobs.
- Develop a definition of sustainable practices to certify biomass sources that is affordable by Michigan landowners and is acceptable to environmental interest groups.

Rationale for Renewable Power

Recognizing that a significant increase in renewable electrical power will involve capital investment, facility change and likely equalized cost increase to customers, it is useful to clarify the rationale. The following might be arguments for change:

- **Concerns with continued use of coal** – Except for CO2 emissions (discussed separately), concerns are generally for health effects of particulate, metals especially Hg, coal ash disposal, and for acid deposition impact from sulfur. EPA is addressing these concerns through various regulations, although interest groups argue for faster progress. The discussion is more passionate than fact-based, and it is not clear if state action ahead of EPA would justify the cost.
- **Sustainable supply of energy** – While renewable energy may be viewed as fully sustainable, the supply of coal within the US is known to be well over 100 years, the current supply of natural gas appears more than adequate depending upon acceptance of fracking, and nuclear fuel supply is less a concern than reaching agreement on waste disposal, so continuing supply of the current fuel mix is not a compelling argument for change. An exception can be local power plants with difficult access to fossil energy.
- **Support for Michigan resources and businesses** – With the exception of existing renewable power, essentially all energy for power is imported into Michigan, facility design and engineering are often imported in part, while construction and operation are primarily Michigan jobs. Renewable power is viewed as an opportunity for increased Michigan resources and Michigan jobs, retaining cost of importing within the state economy. To the extent that this is actually accomplished, including the resource supply and the facility construction and operation, Michigan economic impact should be considered in the decision to increase renewable power and the likely technology pathways to be followed. Time-bound jobs, such as manufacturing and construction, should be distinct from continuing jobs, such as fuel supply and operations.
- **Environmental concerns / climate change** – The scientific evidence is very compelling that the global climate is changing and the consequences may be severe. While the political debate about responsibility and actions continues, the facts are clear that fossil fuel burning, causing fossil CO2 emissions, is the primary cause, and that coal power plants are major sources. Since changes to power generation facilities must be long-term decisions, it is likely that choices made now will still be within their operating lifetime when the impact of climate change becomes more apparent. Regulations at that point could force immediate change, and short-term response can be less than optimal. Actions that can be taken now that enable long-term fossil CO2 strategies consistent with probable climate change scenarios, but do not disrupt existing investment and operations, should have high value. It should be made clear that the over-riding intent of renewable energy requirements is to drive down fossil CO2 release in a gradual, progressive schedule over a time period of at least 30 years, in support of reasonable business planning, with checkpoints and corrections along the way to stay aligned with science and regulations. For guidance, the publications of the UN Intergovernmental Panel on Climate Change (IPCC, 2007) should be considered. For example, the median of Category 1 would require a 20% reduction of total CO2 mass emissions by 2025, based upon 2000 emissions, Figure 1. Any increase since 2000 due to growth would need to be overcome in addition. Other checkpoints along a continuing trajectory out to 2050 could be proposed, subject to review. Credits and trading can provide flexibility.

  Having long-term targets will assist utilities with facility planning in preparation for eventual fossil CO2 emission regulation, and avoid the high customer cost of surprise.

Renewable Power Choices

The February 15, 2013 Report on the Implementation of PA295 (MPSC, 2013) describes that wind power will be the technology of choice for 94% of all approved projects through 2012. Solar, landfill gas, anaerobic digestion and hydro are useful in specific situations and should continue to be developed and applied in such situations, but do not provide sufficient cost-effective resource to justify a substantial increase in renewable power requirements. The exception is biomass, which is a very large resource in Michigan but has been limited in application for several reasons. These limitations and coming technological solutions are described separately below.

If interest in renewable power in Michigan is actually interest in reduction of fossil CO2 emissions, then Michigan could include advanced technology power as some portion of the total requirement, as done in Ohio (OhioRPS, 2012). Including up to 10% of a total requirement of 30%, for example, to encourage more nuclear or fossil fuel high efficiency combined cycle power + carbon sequestration, would send an important message about fossil CO2 emissions and would provide large utilities with long-term flexibility.

Depending upon wind power to achieve a substantial increase in renewable power has considerable risk:

- Since first installations are built in the best wind zones for high capacity factor and low cost, future installations will have to be located in zones with lower wind, and high tower/long turbine blade technology will be pressed to maintain capacity factor.
- Migration to offshore sites to access high wind zones raises installation cost several times depending upon water depth. Public resistance to near-shore site proposals has been more intense than on-land sites.
- Comprehensive infrastructure grid integration is needed with natural gas turbine backup to provide the baseload capacity necessary to offset coal power, and these costs need to be included in any comparison of CO2 impact. An Argonne study for the State of Illinois found that up to 20% wind power could be counted in baseload if the full state grid could be integrated and if sufficient natural gas turbines were available for fast response ramp-up to track accurate weather prediction (Valentino, 2012). Wind plus gas turbine power could be given baseload priority over coal if the natural gas/coal ratio is high enough and wind prediction is accurate with at least a one hour lead. Illinois power uses about 41% coal and 33% natural gas (2006), compared with 66% coal and 8% natural gas in Michigan in 2009 (LARA, 2011), so significant gas turbine investment would be needed in Michigan to reach the fast response capability in this Illinois study.
- Use of electricity storage can increase the use of wind power for baseload, but battery or capacitor storage remains much too expensive for significant impact. Pumped hydro is useful where available, but the opportunity is limited and largely already taken.
- Use of natural gas backup reduces the CO2 emission benefit of wind since natural gas is a fossil fuel. The CO2 emissions from natural gas are about one-half the CO2 emissions from coal, and even less when high efficiency turbines are replacing current steam coal. So natural gas to replace coal is useful for the near term until future CO2 emission limits decrease below about 50% of present. This limits the lifetime of natural gas installations and eventually leads to another investment in power plant equipment, probably before gas turbine end of life. Carbon capture and storage with new gas turbine installations resolves this fossil CO2 concern, but with additional current capital cost.
- Increased dependence upon natural gas for power presumes that the current supply and cost of natural gas, supported by fracking technology, will continue. Since natural gas quantity is finite, competitive uses will eventually drive prices higher for home heating and industry, and could lead to increased foreign imports of gas.

- Federal incentives can be useful to encourage initial investment in new technologies, but as installations reach significant commercial level, incentives are not needed, place an unnecessary burden on taxpayers, and create a risk of distortion to a competitive market. Incentives will not continue and should not be included in cost comparisons once the technology exceeds penetration of a few percent.

Biomass Potential in Michigan

MSU has estimated the sustainable biomass energy resource in Michigan could be 40 million dry tons per year without impacting food supply, agricultural land, forest health, recreation or wood products (Cook, 2010). Not all of this can be readily harvested, and perhaps half should be left available for transportation biofuels, but focused research should be able to provide continuing increases in yield. 16 M dry tons would offset 30% of the coal used for power in Michigan currently, which would make $0.4B of coal import cost available to be spent in Michigan biomass businesses. If this biomass could be co-fired in existing coal plants, then a 30% reduction in coal CO2 emissions and a 20% renewable power target could be achieved without new construction (coal is 66% of total electric power in Michigan).

If 16 million dry tons is also reserved for biofuels, then 20% of imported petroleum products could be offset, retaining over $2.5B for business development within Michigan. On a nation-wide scale, increasing supply of biomass (ORNL, 2011) will be sufficient to match an increasing demand for both power and transportation, Figures 2 and 3. Biomass for power will not detract from biomass for transportation because biofuel plant build rates are limited by plant complexity and cost (NRC, 2009). The supply of torrified biomass for power can be in place before the biofuel plants are built or are able to utilize much biomass, Figures 4 and 5. Torrefied pellets will be convenient to transport and store biomass for biofuel plants as well as biopower plants, depending upon the fuel synthesis process used.

These reductions in fossil CO2 emissions through use of bioenergy, and efficiency actions underway within these industries, are sufficient to allow both power and transportation to follow a reasonable fossil CO2 trajectory through at least 2030, Figure 1. This provides the flexibility to respond to climate change regulation without economic disruption.

Biomass Power Growth and Challenges

Biomass power in Michigan is about 1.7% of total electric power (43% of total renewable power x 4% renewable fraction in 2009), primarily from 7 dedicated wood power plants (Melow, 2013), (LARA, 2011). Various small boilers for heat are also being converted to biomass where economics or local interests prevail, but the impact on total state energy use is small. With the possible exception of L'Anse Warden, all of these power plants predate PA295. And biomass power is a small portion of plans for 2015 (MPSC, 2013), so compliance with PA295 is not currently a driver for biomass power. Local economics would need to justify a new plant dedicated to biomass. Biomass plant size is typically less than 50 MW since biomass delivery is by truck and is considered too expensive beyond 50 miles gathering radius. Large utilities have little interest in biomass co-firing due to uncertain supply and biomass handling cost, compared with wind power with incentives. After studying biomass co-firing, Wyandotte decided to proceed with wind because of the cost of the parallel biomass feed system required to maintain rating (Wyandotte, 2010).

Biomass power comparisons often cite EIA equalized cost, which typically assumes that any biomass plant would be an all-new installation of latest combined-cycle technology, which is best for efficiency, but the capital cost, together with fuel cost higher than current coal or natural gas, makes this choice uncompetitive with current installed coal plants and incentives (AEO2011, 2011).

In contrast, European utilities, required to use 20% renewable energy by 2020, are expected to double wood pellet imports, much of it from the southern USA (Flach, 2013), and a large portion of this could be torrefied pellets if co-fire trials now underway continue to be successful.

To become a supplier to a European utility, a wood pellet producer must comply with the European requirements for sustainable biomass. Small, private forest owners have found that the present standards to certify their biomass are more comprehensive and expensive than they can afford. Similarly, a proposal by the University of North Carolina to begin to co-fire biomass has not yet been implemented due to difficulty to find a supplier who could comply with their sustainability requirements. A compromise definition is needed to assure sustainable, renewable biomass supply at affordable cost for forest owners.

A fresh approach is needed for Michigan, and the USA, to take advantage of the extensive biomass resource potential to increase renewable energy utilization.

Torrefaction Benefits

Instead of building new power plants or significantly revising existing plants to accept biomass, the biomass can be thermally treated to match existing plant requirements. This mild pyrolysis process, called torrefaction, modifies the properties of the biomass to closely match the properties of western coal, which is 80% of the coal used in Michigan and an increasing fraction of national coal use. Pellets or briquettes of torrefied biomass can be mixed with coal in the desired fraction, fed through existing coal handling systems, and burned efficiently in existing boilers.

By investing in pre-treatment of the biomass at local biomass collection centers instead of investment at the power plant, total capital cost is reduced and existing power plant operations are not interrupted. Torrefied pellets can be produced near the biomass source and shipped by rail or ship and be received at the plant just as coal is received. Torrefaction near sources is preferred because improved energy density, pellet durability, and water shedding properties (hydrophobic) simplify and lower the cost of transport. Savings in transport can offset the cost of the torrefaction reactor to a large extent. Since transport is similar to coal, gathering distance can be much larger than with un-treated biomass. This removes the size limitation of the power plant using biomass. For example, large coal power plants in southern Michigan could receive torrefied pellets from the northern LP by rail or from the UP by Great Lakes shipping at a fraction of the transport distance for Powder River Basin coal. Establishing long term contracts for biomass products would support sustainable businesses and jobs in these communities where they are needed.

The torrefaction process and properties are well described in the literature (Bergman, 2005), (Bergman2, 2005). Following are key properties relevant to co-firing in large coal power plants.

- Torrefaction causes decomposition of some hemicellulose, but not much cellulose or lignin. The product loses woody fibers and becomes friable, like charcoal, so that it is easily ground to a fine powder and can be formed into pellets or briquettes to match coal chunks. Coal crushers and grinders are adequate. Torrefied chip deterioration and dust can be concerns unless torrefied biomass is densified into pellets before handling.
- Torrefaction removes moisture and light hydrocarbons which result from hemicellulose decomposition. Hydrocarbons are captured and used for process heat, making the system self-sustaining once operational.

- Energy density is similar to PRB coal, and can be increased with more severe processing. Mass of the product is 30% less than the feedstock, but energy content is reduced only 10% because most carbon is retained.
- Energy content and combustion properties will support rated power at any co-firing ratio at a plant using sub-bituminous (PRB) coal. Plants using bituminous coal will need increased feedrate or reduced co-fire ratio to operate at rating.
- Torrefied biomass is hydrophobic, so that pellets transported in open rail cars and stored in coal yards will reject most water. Long term storage or freeze/thaw may lead to pellet deterioration if densification is not adequate, and binder additives may be needed. Confirmation testing is incomplete.
- Torrefied biomass should be considered similar to the untreated source biomass in terms of corrosion and slagging due to chlorine and alkali content. Concerns for co-firing in existing coal plants can be addressed by using woody biomass, and avoiding herbaceous biomass, agricultural residual and municipal waste. Washing methods are being developed to resolve these concerns. Also, herbaceous biomass is a good source for biofuels, which will remove any troublesome composition during fuel synthesis processing. So biomass sources are naturally matched with end use: wood to biopower and grasses to biofuel.
- Disposal approved for coal ash, such as in cement, is not necessarily approved for biomass ash due to differences in ash composition. Confirmation testing and approval, or development of other uses, are needed.

Torrefaction Activities

Torrefaction appeared in the 1800s as a means to provide municipal gas from biomass for lighting. Recent interest stems from European requirements for renewable energy use in coal power plants. A large number of announcements have been made in Europe and in North America, using a wide range of biomass heat treat equipment (Melin, 2011), but commissioning these plants has progressed more slowly than anticipated as companies experience scale-up learning. Several companies now appear to be reaching commercial supply capability, and utilities are preparing trials and discussing supply contracts. While current capacity in intended for Europe, several producers invite discussion of projects to install their plants on customer sites. A declaration of intent to use torrefied biomass would likely open discussion with one or more producers to build in Michigan.

In addition to development of demonstration scale facilities by producers, now moving toward commercial scale, advanced technology to optimize the process and the reactor system is active at universities and research institutes. Extensive research has been done at ECN in the Netherlands (Bergman, 2005), and they were instrumental in forming the SECTOR collaboration, now with 21 partners including researchers, producers and utilities from 9 EU countries to further the knowledge of torrefaction and expedite implementation (SECTOR, 2012). In North America, Natural Resources Canada is working with the Wood Pellet Association of Canada and with several producers and users to conduct a joint demonstration (Medrali, 2011). In the USA, DOE activities are centered at the Idaho National Lab (Tumuluru, 2010), and power generation research is conducted by the Electric Power Research Institute (O'Connor, 2011). Universities involved in torrefaction studies include North Carolina State, Penn State, Iowa State, and Minnesota. In Michigan, Dr. Christopher Saffron, an author of this submission, is actively involved in research, technology development and teaching of pyrolysis of biomass, including torrefaction, at MSU. Dr. Ezra Bar-Ziv, Professor, Mechanical Engineering at MTU, is developing a torrefaction system and is aligned with E.B. Clean Energy in Israel.

Renewable Power Opportunity for Michigan

Michigan has sufficient resources to proceed with renewable power requirements of 20-30%. A migration plan extending over 20 years, with a check point in 10 years, would allow businesses to plan and to utilize remaining useful life in existing facilities. This will encourage long term investment to be consistent with eventual constraints on fossil carbon emissions. A portion of the cost to import coal and natural gas into Michigan can be retained and invested in state businesses and jobs. Businesses and jobs based in biomass power will be sustainable indefinitely.

Depending primarily upon wind power to achieve these levels brings considerable risk. Biomass power must be a substantial contributor in order to impact dispatchable power. Torrefaction is the key technology to enable biomass power to reach this potential, because co-firing of 20-30% in existing large coal plants will then be possible anywhere in the state. Since capital cost is simply the torrefaction reactor at local processing centers without impacting the power plant, cost of new power plant construction is avoided, and the higher cost of feedstock can be largely offset, Table 1.

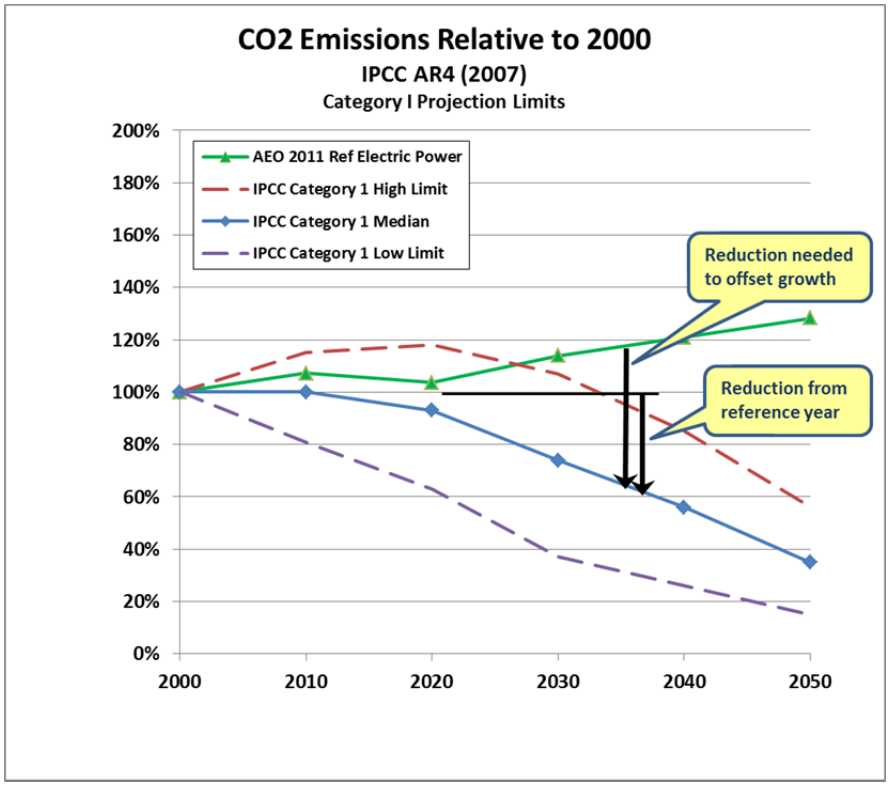

Figure 1. A CO2 reduction schedule based on IPCC Category 1 (IPCC, 2007)

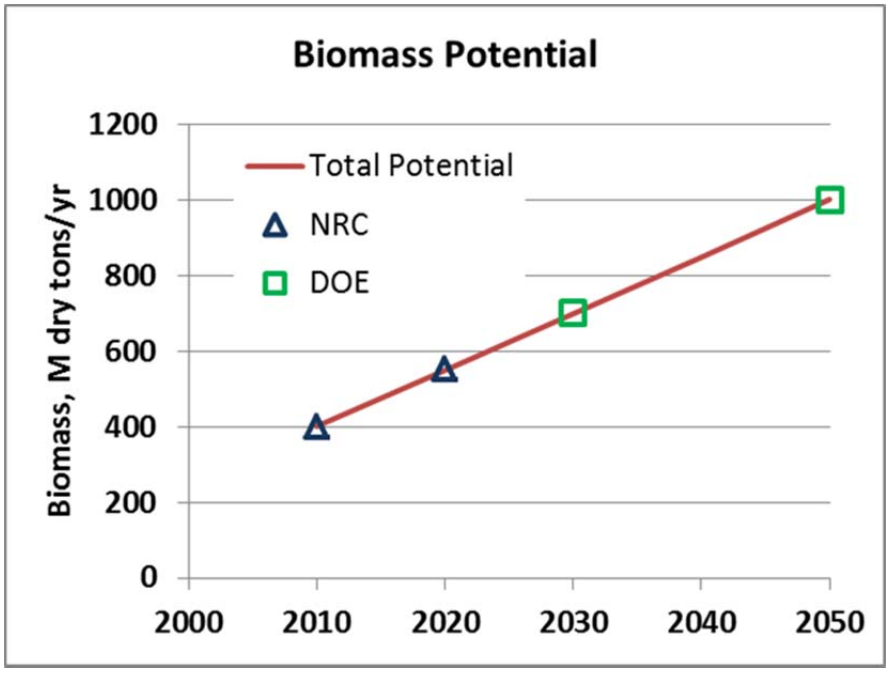

Figure 2. The NRC (NRC, 2009) and DOE (ORNL, 2011) agree on bioenergy potential for the USA

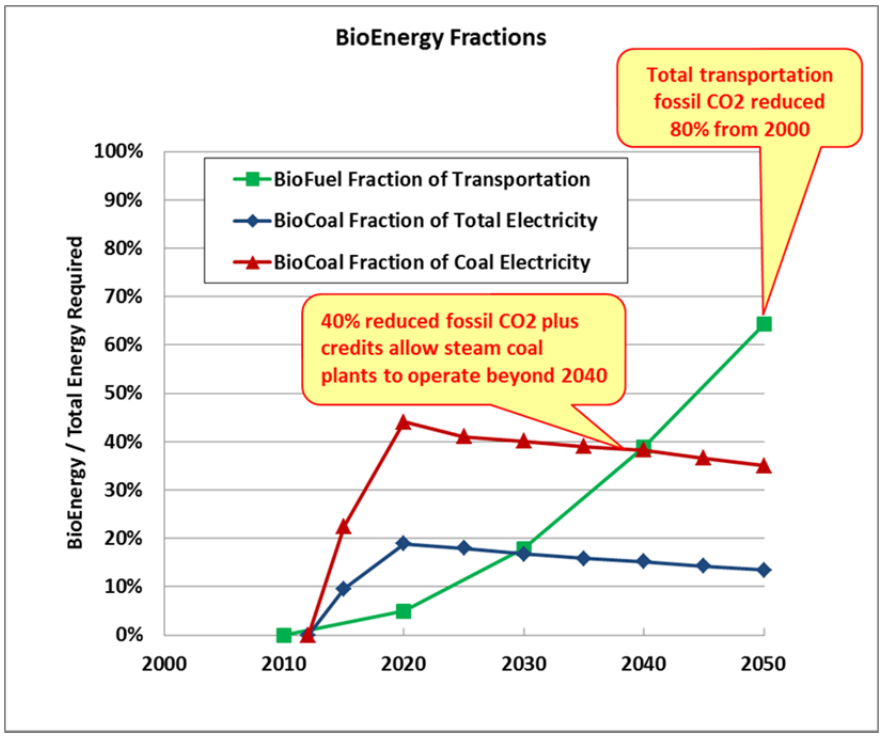

Figure 3. The biomass supply can support both nationwide power and transportation as their demand develops to comply with future CO2 constraints.

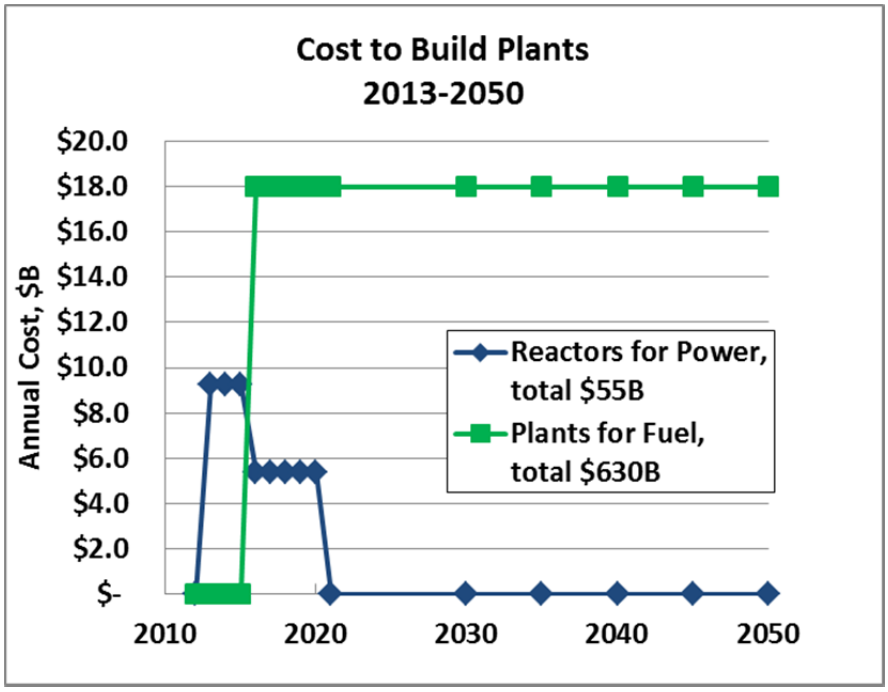

Figure 4. Biofuel synthesis plants are complex and build rate will pace the demand for biomass, leaving adequate supply for power. Torrefaction reactors to support 20% biopower could be built in 10 years at half the annual cost.

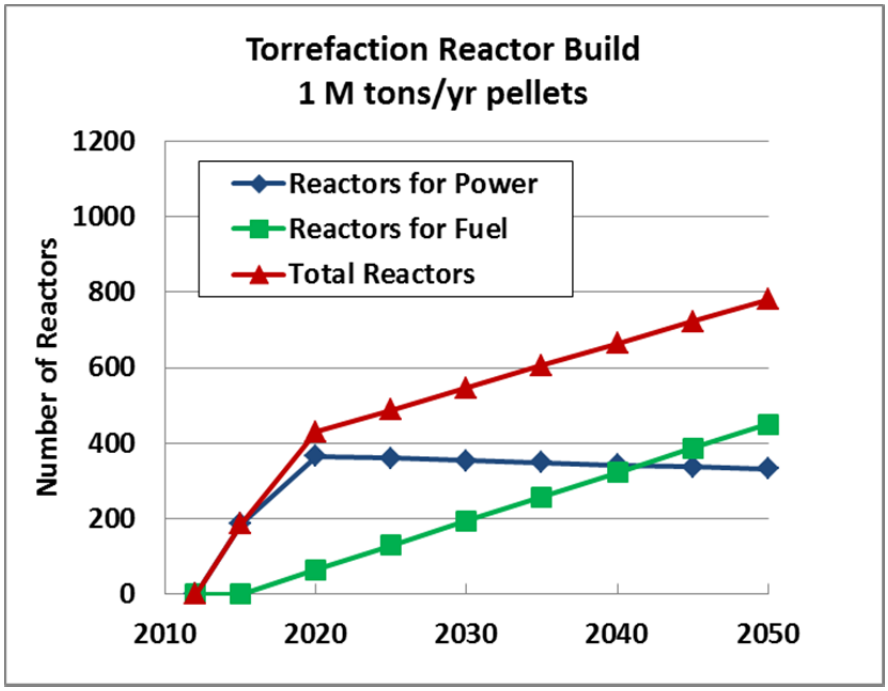

Figure 5. Total reactors needed (at 1M tons/yr each) for 20% biopower nationwide can be completed in time to support builds for biofuel plants, if torrefied pellets are also preferred for biofuel feedstock.

Plant Type	Overnight Capital, $/kW	Capacity Factor	U.S. Average Levelized Cost, $/MWHr				
			Capital	Fixed O&M	Variable O&M (fuel)	Trans-mission	Total Levelized Cost
Fossil Fuel Plants							
Existing coal upgrade	22	0.85	0.5	0.0	24.3	0.0	24.8
New conventional coal	2810	0.85	65.3	3.9	24.3	1.2	94.7
New nat'l gas combined cycle	967	0.87	17.5	1.9	45.6	1.2	66.2
Renewable (non-fossil) Plants							
New Adv Coal IGCC with CCS	5287	0.85	92.7	9.2	33.1	1.2	136.2
New Adv Gas IGCC with CCS	2036	0.87	34.6	3.9	49.6	1.2	89.3
Wind onshore	2409	0.34	83.9	9.6	0.0	3.5	97.0
Wind offshore	6056	0.34	209.3	28.1	0.0	5.9	243.3
Solar thermal	4636	0.18	259.4	46.6	0.0	5.8	311.8
Biomass wood chip boiler	3724	0.83	55.3	13.7	42.3	1.3	112.6
Torrefied pellets in existing coal	650	0.85	15.0	0.0	47.0	0.0	62.0

Adapted from Annual Energy Outlook 2011, EIA, http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

Table 1. Torrefied biomass pellets used in an existing coal plant, instead of building a new wood chip boiler, provides a competitive renewable pathway, especially when cost is blended at a specific co-firing ratio with existing coal.

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