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Competition for biomass among renewable energy policies: Liquid fuels mandate versus renewable electricity mandate

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Summary

FAPRI-MU estimated the market impacts of a hypothetical federal Renewable Portfolio Standard (RPS) on US agricultural and energy markets based on 500 simulations of economic models. The hypothetical RPS requires that 10% of electricity is generated from renewable resources in 2010/11, rising to 20% by marketing year 2020/21. All renewable energies (biomass, hydropower, wind, solar, geothermal, or similar sources) count equally towards meeting the RPS.

Considering the average results for 2018/19-2020/21:

- Based on assumed technology patterns, biomass supplies respond faster than competing renewable energy sources, so the introduction of the RPS causes biomass used for electricity nearly to double.
- RPS compliance costs are measured in tens of billions of dollars, depending on the assumptions. Consumers electricity prices rise.
- Biomass drawn into electricity use causes a slight reduction in biomass used for liquid fuel. This result depends on whether or not the cellulosic mandate is waived and biomass market structure.
- The increase in warm season grasses area displaces some traditional crops, particularly hay. This effect is limited if more than half of warm season grass area is drawn from land previously given to other uses.
- The value of crop residues, such as corn stover and wheat straw, also rises, improving net returns to growing these crops.
- The small reductions in traditional crop area lead to slightly higher crop prices.
- Farm income is higher because of higher returns to biomass and higher crop prices. Agricultural program cost effects are very small.

We find that there are several sources of uncertainty.

- Warm season grasses expansion is limited if they compete more with traditional crops for land, and crop residue use for bioenergy expands to help meet the RPS.
- Our technology path is modest relative to optimistic studies reported in the literature. An even slower pace would lead to higher compliance costs.
- EPA decisions to waive or not to waive the cellulosic biofuel mandate affects the RPS compliance cost estimates and can determine the directional impact of introducing an RPS on biofuel mandate compliance costs.

Further assumptions relate to the biomass supply. Biomass transportation and storage costs remain high, limiting the development of national or even regional markets for biomass feedstocks. We also assume that only a portion of land allocated to warm season grasses displaces traditional crops, such as wheat and hay.

Introduction

FAPRI-MU has developed structural economic models that represent the interactions of agriculture and energy markets. [1] These models include equations that represent biomass supply from corn stover, wheat straw, forest matter, warm season grasses, and municipal solid waste. Each of the biomass feedstock types can be used for biofuel or renewable electricity production.

These models are used to analyze a hypothetical federal *Renewable Portfolio Standard (RPS)*. The RPS requires that at least a certain share of electricity generation is made from renewable resources. The analysis starts from the FAPRI-MU January 2011 baseline adjusted with the introduction of new biomass supplies and energy markets links. Baseline data for energy markets are from EIA's 2011 Annual Outlook.

Key assumptions

- **RPS**: The federal RPS starts at 10% in 2010 and climbs to 20% in 2020. Biomass, geothermal, wind, solar[2], hydro, and certain other renewable energy sources qualify, and all count equally towards the RPS. Energy efficiency savings do not count towards the RPS, so renewable energy use is required. Costs are initially paid by electricity providers, but eventually passed on to consumers in the form of higher electricity prices.
- **RFS**: The Renewable Fuel Standard sets out minimum use requirements for different biofuels. However, the mandate for biofuel made from cellulosic biomass is waived. Other mandates are adjusted, so total use is also lower.[3] The case of an unwaived mandate is explored (page 18).
- **Other support**[4]: Existing support to renewable energies is drawn from various publications. The Database of State Incentives for Renewables & Efficiency (DSIRE) is used to represent all state RPSs as a single share of all US electricity use.[5] US Treasury tax expenditure estimates are used as production subsidies.[6] Where available, we include subsidies to wind and solar power.
- **Technology**: Supply potential in 2022 is initially calibrated to the few studies that report price and quantity estimates, but we assume slower development. An even slower pace of technology development is possible (page 16). We assume biomass from warm season grasses displaces some traditional crops, and that national biomass markets do not develop because of high transportation costs.
- **Competition**: An acre of warm season grass displaces 0.4 acre of traditional crop land before considering price effects. A higher rate is tested (page 20).

Model simulations are stochastic. Key determining factors are varied randomly, including crop yield shocks, petroleum price, demands for crop exports and livestock products, and many supplies and demands in energy markets. Data reported in the tables represent the averages of stochastic simulations. The analysis focuses on the impacts on market prices and quantities, not broader welfare or environmental effects.

Policy assumptions

Calendar or marketing year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Renewable Portfolio Standard (RPS)					(percent of national electricity generation)					
Federal RPS, baseline	0	0	0	0	0	0	0	0	0	0
Federal RPS, scenario	11	12	13	14	15	16	17	18	19	20
Other renewable energy policies										
					(billion dollars)					
Federal tax credits, excl hydro	2.0	2.8	3.2	2.7	2.0	1.8	1.8	1.8	1.8	1.8
					(percent of costs)					
Federal grant	30	30	0	0	0	0	0	0	0	0
Renewable Fuel Standard (RFS), MY					(billion gallons)					
averages assuming cellulosic mandate is waived										
Total RFS, less waived amount	14.5	15.7	16.6	18.1	19.3	20.4	21.8	23.4	24.8	25.6
Advanced, less waived amount	1.5	2.1	2.4	3.3	4.3	5.4	6.8	8.4	9.8	10.6
Biomass-based diesel	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cellulosic mandate, reset with waiver	0.1	0.4	0.4	0.9	1.4	2.1	3.0	4.0	5.3	6.1

Baseline values of key parameters in 2020/21

	Grasses	Straw	Stover	Forest	Munic. Waste
Transportation cost					
Biomass for electricity (dollars/ton)	62.5	68.2	68.2	42.8	42.8
Biomass-to-electricity processing					
Electricity per ton (mil. btu/ton)	5.5	5.5	5.2	5.7	5.6
Costs, other than feedstock (dollars/mil. btu	22.39	22.39	22.39	22.39	53.08
Biomass-to-fuel processing					
Ethanol yield (gallons/ton)	82.7	79.7	80.2	68.4	89.6
Co-produced electricity, net (thou. btu/ton)	6.1	6.1	6.1	9.1	9.1
Costs, other than feedstock (dollar/gallon)	0.75	0.75	0.75	1.18	1.18

Area effects of warm season grasses (acre change in crop area per acre in warm season grasses at fixed prices)

Corn area	-0.03	Wheat area	-0.14	Other crops	-0.05
Soybean area	-0.04	Hay area	-0.14	Total	-0.40

Cross-effect of biomass for electricity and liquid fuel uses (dry tons change in one use for a dry tons in the other use) -0.40

Electricity market effects

We focus on the average effects over all simulations in the last three years of the projection period. The RPS is binding in these years; electricity producers are required to purchase more renewables than they do in the baseline without the RPS.[7]

Biomass-based electricity nearly doubles, on average, as compared to the baseline. Other renewables, including hydro and solar electricity, rise more slowly. Because biomass helps to meet the binding RPS and because we assume roughly identical costs of generating electricity from all types of biomass, the price plants are willing to pay for biomass feedstocks rises by about one-half over the baseline prices.[8]

Domestic coal use for electricity and coal price both fall based on the assumption that biomass tends mostly to displace coal. Assuming that the RPS does not apply to other users of natural gas, such as industry, these uses rise somewhat as the rising price of electricity causes some substitution. The natural gas price decrease is smaller than the coal price decrease.

The electricity generation sector bears the cost of complying with the RPS initially. We assume that they try to pass this new cost of doing business on to consumers in the form of higher electricity prices. As prices adjust overall, the net effect is still an increase in the price to consumers, but less than the full cost of the mandate as producer prices also change. The increase in consumer price constitutes about 60% of the cost of mandate compliance.

We assume that the RPS is implemented using tradable Renewable Energy Certificates (RECs) to prove compliance with the RPS.[9] The average REC price represents a substantial amount that equals somewhat less than one-half the electricity price, indicating a high premium on renewable energy sources with the RPS in place. The cost of complying with the mandate, ignoring transaction costs, averages $28 billion in the final three years of the projection period over all simulations.

The mandate compliance costs are sensitive to competition for land, the pace of technology development relating to biomass production and use, and implementation of the cellulosic biofuel mandate, as shown later. The result is also sensitive to the exact level of the RPS and how it can be achieved. For example, the RPS might be non-binding if set at a lower level or if it can be met with energy efficiency. A longer time frame that allows other renewables to adjust, and more biomass as well, could also decrease the price and biomass impacts.

Electricity and renewable electricity markets

2018/19-2020/21 averages	Baseline	RPS Scenario	Difference	Percent
Electricty production		(trillion btu)		
Natural gas	3,450	3,397	-53	-2%
Coal	6,395	5,864	-531	-8%
Biomass	416	804	388	93%
Other renewables	1,924	2,051	127	7%
Other electricity	3,196	3,071	-125	-4%
Total	15,381	15,187	-194	-1%
Feedstock plant prices		(dollars per million btu)		
Natural gas	5.81	5.84	0.03	0%
Coal	2.94	2.72	-0.22	-7%
Warm season grasses	7.26	10.90	3.64	50%
Corn stover	7.26	10.92	3.65	50%
Wheat straw	7.26	10.90	3.64	50%
Forest matter	7.25	10.89	3.64	50%
Municipal waste	7.25	10.90	3.64	50%
Electricity price		(dollars per million btu)		
Industrial , to consmers	20.85	21.92	1.08	5%
Mandate price		(dollars per million btu)		
Renewable electricity certificate	n.a.	9.56	9.56	n.a.
		(billion dollars)		
Mandate cost	n.a.	28	28	n.a.

Biomass

Total biomass for electricity generation with the RPS is about double the baseline amount, on average. More biomass is drawn from all five sources. In relative terms, the increases are largest for corn stover, wheat straw, and warm season grasses. However, warm season grasses and forest matter increase the most in absolute terms. The share of forest matter in biomass-based electricity output remains close to one-half of the total with the RPS, as compared to almost 60% in the baseline.[10]

Electricity plants bid the sum of the electricity price and the REC price into the price of biomass. In the last three years of the period, their willingness to pay for biomass approximately doubles, depending on the biomass, relative to the no-RPS baseline.

The value of biomass-based liquid fuels also rises. A look at studies of future cellulosic biofuel production methods suggests that these processes are net producers of electricity. Assuming that electricity sold from a cellulosic biofuel refinery can help to meet the RPS, the farm price of biomass for liquid fuel is also bid higher. This higher price is not enough to offset the negative effect of more biomass purchases for renewable electricity generation, however. The average net effect is a reduction in biomass used to make liquid fuels overall, but there is an increase in some sources.

A key assumption is that biomass is too bulky to be transported far or stored for long. We do not represent these markets as though there would be a single national benchmark price, as is the case for most many other crops. Instead, biomass markets are locally determined and there is limited competition among refineries for these feedstocks, although refineries do compete to sell their outputs. Because we do not assume a single market for any of these biomass feedstocks, prices for biomass for liquid fuel or electricity can differ substantially.[11]

Greater competition for biomass, as might occur if biomass transportation costs fell dramatically, would reduce the potential for price differentials among biomass types and uses, perhaps causing a greater reallocation among types and from one use to the other, as well as more biomass supplies overall.

Biomass feedstocks

2018/19-2020/21 averages	Baseline	RPS Scenario	Difference	Percent
		(million dry tons)		
Supplies of biomass for electricity				
Warm season grasses	14.3	37.8	23.5	164%
Wheat straw	2.6	7.1	4.5	171%
Forest matter	39.5	62.7	23.2	59%
Corn stover	8.0	24.6	16.6	208%
Municipal waste	4.2	5.4	1.2	30%
Total	68.5	137.5	69.0	101%
Supplies of biomass for liquid fuels				
Warm season grasses	30.3	25.9	-4.3	-14%
Wheat straw	3.4	3.8	0.4	12%
Forest matter	0.0	0.1	0.0	32%
Corn stover	21.6	19.2	-2.4	-11%
Municipal waste	0.8	0.8	0.1	7%
Total	56.1	49.9	-6.2	-11%
		(dollars per dry ton)		
Farm prices, biomass for electricity				
Warm season grasses	52.9	111.4	58.5	111%
Wheat straw	45.8	103.9	58.1	127%
Forest matter	74.8	133.7	58.9	79%
Corn stover	40.5	96.0	55.5	137%
Municipal waste	73.1	131.2	58.1	79%
Farm price, biomass for liquid fuels				
Warm season grasses	59.2	64.2	5.0	9%
Wheat straw	49.6	54.8	5.2	10%
Forest matter	6.3	10.0	3.7	59%
Corn stover	49.3	54.5	5.2	11%
Municipal waste	-7.2	-1.2	6.0	n.a.

Biofuel markets and policies

In these simulations, we assume the cellulosic biofuel mandate is waived in each year and set at a new level according to the supply capacity.[12] As the cellulosic biofuel supply capacity depends on prices and costs, the required minimum level of cellulosic biofuel is not a constant preset level determined by policy. Instead, the supply capacity is reduced in the event that the RPS creates competition for biomass. Based on the expectation that waived amounts are set based on capacity and capacity depends on price signals, the average cellulosic ethanol production is lower in the last three years relative to the baseline without the RPS.

With less ethanol supplied, the average retail ethanol price implicit in blended fuels is higher. These changes tend to reduce prices of Renewable Identification Numbers (RINs), the biofuel mandate compliance certificate. The mandate is easier to meet if less biofuel has to be sold.

The refinery prices of the ethanol change very little. Fuel blenders would be willing to pay more for ethanol because of the higher retail price, but the value of the ethanol in helping to meet the mandate is slightly lower because the RIN prices are lower. The contrasting effects result in only small changes in wholesale ethanol prices.

Biodiesel market impacts are small. There are many forces acting on biodiesel, such as impacts on soybean and soybean oil markets through competition for area, interaction between distillers grain and soybean meal in animal feeds, cross effects between diesel-type fuels and gasoline-type fuels, and the use of biodiesel to help meet advanced and overall mandates, as well as the biodiesel mandate itself. The end result is more biodiesel production and use, on average, with a lower retail price and a higher RIN price.

Biofuel mandate costs are lower with less cellulosic biofuel use in the RPS scenario as compared to the baseline without an RPS. As discussed earlier, these results are contingent on a cellulosic biofuel mandate waiver, and also on how the new mandate volume is determined. Sensitivity to this assumption is explored later (page 18).

Biofuel supply and use

2018/19-2020/21 averages	Baseline	RPS Scenario	Difference	Percent
Ethanol supply and use		(million gallons)		
Production	21,097	20,577	-520	-2.5%
From corn	15,753	15,763	10	0.1%
Other conventional	237	236	-1	-0.4%
Cellulosic	5,108	4,578	-529	-10.4%
Imports (ethyl alcohol)	2,834	2,855	21	0.7%
Domestic disappearance	23,179	22,704	-475	-2.0%
Exports (ethyl alcohol)	693	676	-17	-2.4%
Biodiesel supply and use				
Production	831	843	12	1.4%
Domestic dissappearance	1,083	1,095	12	1.1%
Net xports	-69	-69	-1	0.9%
Biofuel prices		(dollars per gallon)		
Conventional rack, Omaha	2.02	2.02	0.00	0.1%
AMS spot plant price, Iowa	1.83	1.83	0.00	0.1%
Cellulosic rack	3.35	3.34	-0.01	-0.2%
Other advanced rack	2.44	2.44	0.00	0.1%
Effective ethanol retail	2.34	2.36	0.02	0.9%
Effective biodiesel retail	4.92	4.91	-0.01	-0.3%
RIN values				
Conventional ethanol	0.45	0.42	-0.03	-6.9%
Advanced ethanol	0.88	0.84	-0.03	-3.6%
Cellulosic ethanol	1.79	1.74	-0.04	-2.3%
Biodiesel	1.14	1.14	0.00	0.1%
		(billions of dollars)		
Biofuel mandate compliance costs	22.91	21.16	-1.75	-7.6%

Crop markets, land use, farm income, and CCC costs

The RPS affects land use in at least two ways. Harvesting agricultural residues for bioenergy use adds to the net returns, such as if bioenergy demand for corn stover adds to corn returns and rising wheat straw value adds to wheat returns. In addition, dedicated biomass crops such as warm season grasses may compete with traditional agricultural crops for land.[13]

The competition of warm season grasses and traditional crops for land is based on the assumption that, at any given set of prices, an additional acre allocated to warm season grasses displaces 0.4 acres planted to traditional crops represented in the model, with more than half of that displacement explained by reduction in area allocated to hay and wheat. (This assumption is altered later, to test sensitivity of results.) This initial effect is tempered by price effects, as rising crop prices cause producers to bring some land back into growing traditional crops.

The average 2018/19-2020/21 area effects of introducing the RPS are largest for warm season grasses. Warm season grasses are planted to several million acres more than in the baseline. Although competition with warm season grasses might be expected to reduce corn area, the higher returns from corn stover cause total area allocated to corn to remain about the same, on average. The net effect of a higher value on wheat straw and greater competition with warm season grasses on wheat area is a small reduction. Area allocated to other crops decreases to make way for warm season grasses, but the largest reduction is in hay area, which is reduced by as much as any other crop, on average. The average increase in total area planted to warm season grasses plus traditional crops and hay is 2.2 million acres as compared to the baseline. Conservation Reserve Program (CRP) area decreases by a very small amount, assuming that there is no direct substitution between the CRP and warm season grasses. These results suggest a reduction in land devoted to pasture and other uses.

The small reductions in land allocated to traditional crops leads to small crop price effects. Average prices of corn, soybeans, and wheat are pennies higher than in the baseline, amounting to less than a 1% increase in each case. The hay price increases by more, the highest increase, relative to the baseline.

Net farm income is higher with the RPS than in the baseline without the RPS. The additional demands for crop residues plus net income from warm season grasses explain most of this result.

Commodity Credit Corporation (CCC) and total mandatory agricultural programs costs are slightly lower, on average. At baseline and RPS crop prices, agricultural program costs are mostly attributable to the Fixed Direct Payments that are constant regardless of prices. Crop insurance program costs are slightly lower.

Crop price, land use, and farm sector effects

2018/19-2020/21 averages	Baseline	RPS Scenario	Difference	Percent
Planted area		(million acres)		
Corn	89.0	89.0	0.0	0.0%
Soybeans	78.0	77.9	-0.2	-0.2%
Wheat	55.2	54.9	-0.3	-0.5%
Warm season grasses	7.3	10.4	3.1	42.9%
Selected other crops	41.6	41.5	-0.1	-0.3%
13 crop planted area	271.1	273.7	2.5	0.9%
Hay harvested area	58.3	58.0	-0.3	-0.6%
CRP area	30.3	30.3	0.0	0.0%
13 crops + hay + CRP	329.4	331.6	2.2	0.7%
Crop prices		(dollars per bushel)		
Corn	4.72	4.73	0.01	0.2%
Soybeans	11.84	11.87	0.03	0.2%
Wheat	5.72	5.74	0.02	0.4%
		(dollars per ton)		
Hay	127.84	129.64	1.80	1.4%
		(billions of dollars)		
Net farm income	100.88	101.87	0.98	1.0%
Net CCC outlays	9.30	9.26	-0.04	-0.4%
Total mandatory outlays, selected programs	21.44	21.42	-0.02	-0.1%

Sensitivity of results

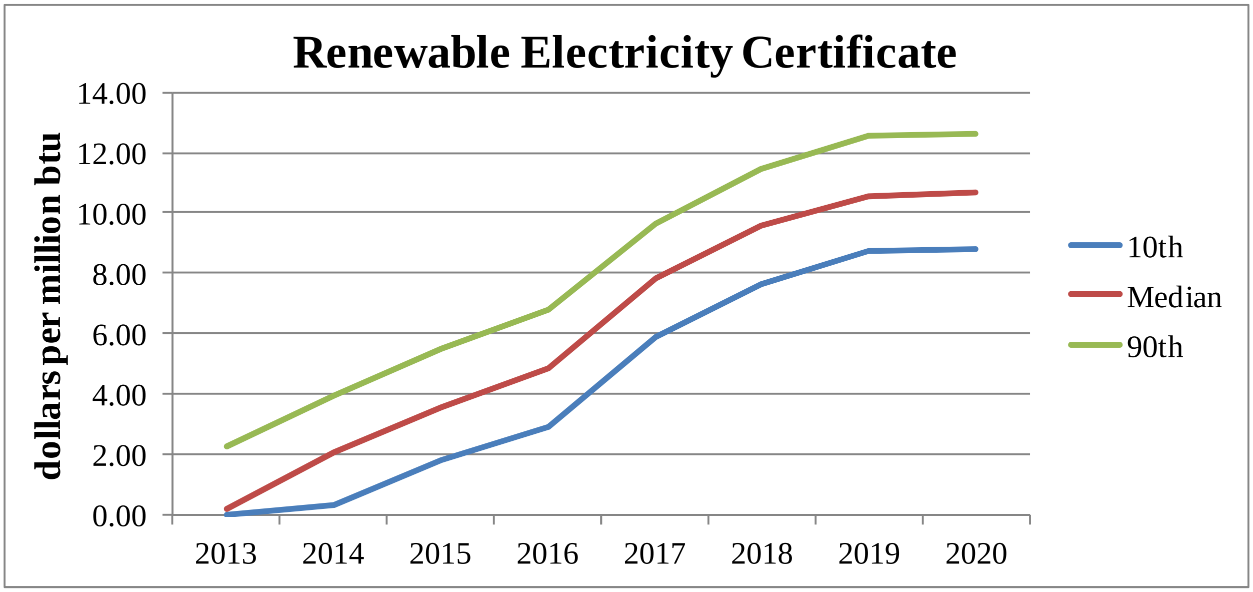
The preceding data represent averages over a wide range of market settings. In stochastic analysis, the economic models are solved hundreds of times to assess how these bioenergy policies operate in a variety of contexts, such as with high or low petroleum prices, demand perturbations, and crop yield shocks. The impacts of a policy that requires at least some minimum level of renewable electricity or biofuel use depend on context. If use exceeds the threshold anyway, then the mandate is not binding and probably has little or no direct effect on the market. Consequently, the difficulty of meeting the requirement of the hypothetical RPS – as well as the existing RFS – depends in part on the shocks to agricultural and energy markets.

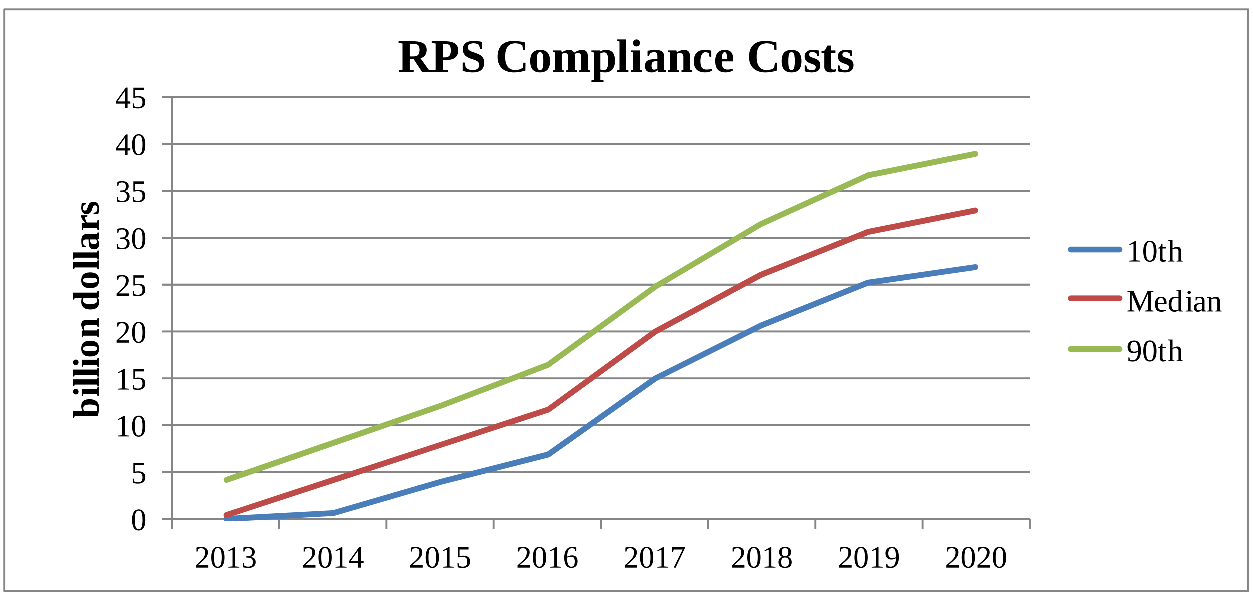
We do not explore sensitivity to certain key factors, not least biomass production and refining technologies which are discussed later. Policies are determined by current law. The cellulosic biofuel mandate waiver is a key question discussed later. In any case, the stochastic exercises here are partial, and do not reflect all the uncertainty about markets and policies in the next ten years.

We also do not explore all the potential impacts of market volatility. Producers and consumers might change their behavior if an RPS causes volatility to increase or decrease. For example, if biomass supplies varies substantially because of the weather, refineries have more trouble finding steady supplies. Fluctuations in renewable electricity supplies and associated RPS compliance costs can lead consumer electricity prices to vary.[14]

The REC price range is one way to consider the sensitivity of results. The median or middle value of all the simulations is quite low in 2013/14 marketing year. The 10th percentile value is zero, indicating that the RPS is not binding in many simulations in 2013/14. Even so, the RPS is substantial in that year under certain circumstances, as shown by the high 90th percentile price. The REC price tends to climb in a simulation as the rising RPS becomes increasingly binding and as renewable energy supplies only start to expand in response. The median price rises to the range of $10-11 per million btu in 2020/21. With the limited variation in determining factors allowed here, the 10th and 90th percentile REC prices are under or over the median value by about 15-20%.

The median RPS compliance cost is low in 2013/14 and the 10th percentile cost is zero. There are no direct costs to a non-binding mandate, and only low costs to an RPS that is barely binding. Again, there is the potential for much higher costs in this year, as shown by the 90th percentile simulation result for compliance costs. As the RPS grows and the cost tends to rise. The median compliance cost in 2020/21 is tends of billions of dollars. The 10th percentile cost is about 20% lower and the 90th percentile cost is about 20% higher, and these values understates the degrees of uncertainty and volatility as we allow only a subset of determining factors to vary in this analysis.





Low pace of biomass technology improvement

A key uncertainty is the development of technologies to grow and transport biomass, and also to convert biomass into liquid fuels. Here, we assume a lower rate of technological advancement both in terms of biomass supplies on farm and conversion into liquid fuel. These rates are much less optimistic than rates that are approximated to progress from the current status of cellulosic bioenergy – e.g. little production with current prices and policies – to 2022 output estimates drawn from other studies.

Approximate Technology Growth Rates

	Baseline (base case)	Low Tech (tested here)	High Tech (not tested here)
Biomass supply	7.5%	5%	20%
Conversion to liquid fuel	10%	5%	10%

Different technology assumptions cause sharp differences in the *no-RPS* cases. The average over all simulations for 2018/19-2020/21 suggests that substantially less biomass is used for electricity relative to the base case and less than half as much biomass used for liquid fuel as in the base case. Warm season grass area is millions of acres lower if technology advances more slowly, reduced by approximately one half, with or without the RPS, relative to the base case.

A key point, however, is that the waiver of the cellulosic mandate permits a reduction in cellulosic biofuel consumption, whether from warm season grasses, corn stover, wheat straw, or other feedstocks. One consequence of a permitted reduction in cellulosic biofuel production and use is an average reduction in RFS compliance costs if it becomes harder to meet this mandate. This assumption is explored elsewhere.

The directional impacts of introducing the RPS are similar overall whether using the original or the lower technology growth rate. The increase in biomass for electricity is smaller as other renewable energies compete better if biomass technology improves more slowly. As productivity is lower, similar area is drawn into biomass production to achieve a smaller increase in biomass output, leading to area effects from an RPS in the low technology scenario are comparable to the base case.

The RPS is simply much more difficult to meet if biomass and bioenergy technologies develop at a slower pace, so the REC price is bid higher, on average, as compared to the base case, and the RPS compliance cost averages somewhat less than 50% higher.

Lower pace of biomass technology improvement

2018/19-2020/21 averages	Baseline tech, no RPS	Baseline tech, RPS	Low Tech, no RPS	Low Tech, RPS
Biomass for energy		(million dry tons)		
Electricity	68.53	137.54	47.77	110.05
Liquid fuel	56.10	49.86	23.70	21.66
Renewable Energy Cert.		(dollars per million btu)		
REC Price	n.a.	9.56	n.a.	14.24
Compliance costs		(billions of dollars)		
Renewable Portfolio Standard	n.a.	27.7	n.a.	40.7
Renewable Fuel Standard	22.9	21.2	14.4	13.5
Planted area		(million acres)		
Corn	89.0	89.0	89.2	89.2
Warm season grasses	7.3	10.4	3.5	6.6
Other planted crops	174.8	174.3	175.3	174.7
13 crop planted area	271.1	273.7	268.0	270.5
Hay	58.3	58.0	58.7	58.3
Farm prices		(dollars per bushel)		
Corn	4.72	4.73	4.73	4.74
Soybeans	11.84	11.87	11.77	11.81
Wheat	5.72	5.74	5.68	5.72
		(dollars per ton)		
Hay	127.84	129.64	125.59	127.66
Warm season grasses, for electricity	52.86	111.36	54.07	141.50
Corn stover, for electricity	40.48	96.01	41.49	124.34
		(billions of dollars)		
Net farm income	100.88	101.87	100.51	101.53
Net CCC outlays	9.30	9.26	9.33	9.27
Total mandatory outlays, selected programs	21.44	21.42	21.48	21.43

Cellulosic biofuel use mandate is not waived

We assume that the cellulosic mandate of the RFS is waived, and reset to a lower level that is based on production capacity. Because one factor that determines the volume of cellulosic capacity is the development of prices over time, the volume of cellulosic ethanol can be higher or lower in different settings. Here, we assume that the cellulosic mandate is not waived so 12-13 billion gallons of cellulosic ethanol must be used by marketing year 2020/21. The pace of technology development is the same as in the base case and initial RPS scenario. Results are contingent on the assumed -0.4 trade-off between biomass uses.

The no-RPS cases vary with and without the cellulosic mandate waived. Even without an RPS for renewable electricity, the unwaived cellulosic mandate of the RFS leads to a large increase in biomass sales in 2018/19-2020/21, roughly double the base case. The land uses are similar with the cellulosic mandate unwaived as observed before with the RPS imposed but the cellulosic mandate waived: warm season grass area averages 10-11 million acres, total area for 13 crops including warm season grasses expanding somewhat, and hay and other crop area contracting.

The RPS in a context of an unwaived RFS adds to demands for biomasses. Biomass for electricity use more than doubles with the RPS added. However, in this case domestic cellulosic biofuel production falls only very little based on the assumption that imported cellulosic biofuels increase, but are not very responsive to prices at least in the short run. As there is less scope to reallocate biomass with the cellulosic mandate unwaived, the RPS is more difficult to meet. The REC price and the RPS compliance cost are higher than in the original scenario. However, the assumption that high transportation and storage costs prevent the development of fully integrated biomass markets leads to only limited impacts from biomass use for biofuel on biomass use for electricity.

Introducing the RPS in the context of an unwaived cellulosic mandate also draws the most area into crop and biomass production of the scenarios explored here. This scenario also generates the highest net farm income because returns to biomass are high (without the reduced productivity of the previous case) and crop prices also tend to be higher than in other scenarios.

Cellulosic mandate not waived

2018/19-2020/21 averages	Cellulosic waived, no RPS	Cellulosic waived, RPS	Not waived, no RPS	Not waived, RPS
Biomass for energy		(million dry tons)		
Electricity	68.53	137.54	58.38	134.30
Liquid fuel	56.10	49.86	113.06	111.97
Renewable Energy Cert.		(dollars per million btu)		
REC Price	n.a.	27.65	n.a.	30.29
Compliance costs		(billions of dollars)		
Renewable Portfolio Standard	n.a.	27.7	n.a.	30.3
Renewable Fuel Standard	22.9	21.2	46.7	47.5
Planted area		(million acres)		
Corn	89.0	89.0	88.8	88.8
Warm season grasses	7.3	10.4	10.7	14.5
Other planted crops	174.8	174.3	174.4	173.8
13 crop planted area	271.1	273.7	274.0	277.2
Hay	58.3	58.0	57.9	57.5
Farm prices		(dollars per bushel)		
Corn	4.72	4.73	4.70	4.71
Soybeans	11.84	11.87	11.91	11.98
Wheat	5.72	5.74	5.74	5.77
		(dollars per ton)		
Hay	127.84	129.64	129.96	132.36
Warm season grasses, for electricity	52.86	111.36	53.29	117.82
Corn stover, for electricity	40.48	96.01	40.74	101.59
		(billions of dollars)		
Net farm income	100.88	101.87	100.95	102.30
Net CCC outlays	9.30	9.26	9.29	9.25
Total mandatory outlays, selected programs	21.44	21.42	21.44	21.47

Greater competition between warm season grasses and other crops

There is considerable speculation about the potential for dedicated biomass crops to compete with traditional crops for land. Some observers have asserted that warm season grasses, such as miscanthus or switchgrass, would be grown on marginal land that is not used for traditional crops. Other observers argue that high prices to biomass could lead farmers to plant warm season grasses on high-yield lands that have been used for crops. In this experiment, the initial assumption of competition is doubled to test this source of uncertainty.

The initial assumption is that an acre of warm season grasses causes a reduction in traditional crops of 0.4 acre, before taking price changes into account. The effect of a change in the crop returns on warm season grass area is similarly modest, totaling 0.2% reduction for a 1% increase in all crop returns.

Doubling these interactions has an impact on the base case even before a hypothetical RPS is introduced. If warm season grasses competes more with traditional land uses, then it expands more slowly, at least it does given our assumption that the cellulosic biofuel mandate is waived to match capacity. Warm season grass area averages just over a third as much as in the original base case when greater competition. The volume of cellulosic biofuel produced for the RFS is much lower, and more of it comes from corn stover and wheat straw.

The hypothetical RPS draws more biomass into electricity generation, but a much smaller portion comes from warm season grasses as compared to the base case. Even with roughly half as great an increase in warm season grass area as in the base case, area planted to other crops, including hay, falls by about as much. The net increase in total area devoted to these uses is about two-fifths as much as in the base case, reflecting the assumption of greater competition for land already devoted to crops.[15] More corn stover and wheat straw are used to meet the RPS, so returns to these crops tend to rise and the potential for reducing corn or wheat area is reduced, or even reversed.

The RPS causes about as much of an increase in farm income as in the base case. However, the change is associated more with the run-up in biomass prices than with an expansion in biomass sales, given the assumption of greater competition for land.

More competition for land makes it harder to achieve the RPS using dedicated biomass crops, so more renewable electricity must be drawn from other sources. The REC is higher under this assumption, and RPS compliance costs are also greater.

Greater competition for land

2018/19-2020/21 averages	Baseline, no RPS	Baseline, RPS	Scenario, no RPS	Scenario, RPS
Biomass for energy		(million dry tons)		
Electricity	68.53	137.54	58.80	126.33
Liquid fuel	56.10	49.86	37.55	35.59
Renewable Energy Cert.		(dollars per million btu)		
REC Price	n.a.	27.65	n.a.	35.41
Compliance costs		(billions of dollars)		
Renewable Portfolio Standard	n.a.	27.7	n.a.	35.4
Renewable Fuel Standard	22.9	21.2	17.6	16.9
Planted area		(million acres)		
Corn	89.0	89.0	89.1	89.1
Warm season grasses	7.3	10.4	2.5	4.0
Other planted crops	174.8	174.3	175.2	174.6
13 crop planted area	271.1	273.7	266.7	267.7
Hay	58.3	58.0	58.6	58.2
Farm prices		(dollars per bushel)		
Corn	4.72	4.73	4.71	4.72
Soybeans	11.84	11.87	11.78	11.83
Wheat	5.72	5.74	5.68	5.71
		(dollars per ton)		
Hay	127.84	129.64	126.25	128.32
Warm season grasses, for electricity	52.86	111.36	53.42	129.78
Corn stover, for electricity	40.48	96.01	40.88	112.99
		(billions of dollars)		
Net farm income	100.9	101.9	100.4	101.4
Net CCC outlays	9.3	9.3	9.3	9.3
Total mandatory outlays, selected programs	21.4	21.4	21.5	21.4

[1] FAPRI-MU Report #12-11 (www.fapri.missouri.edu/).

[2] Solar includes end-user generated solar power.

[3] We explore the complications associated with mandate waivers elsewhere. Summarizing, other methods of waiving the mandate could eliminate the volumes that had been required for the cellulosic mandate, but not make a corresponding reduction the advanced or total mandates. Because the cellulosic mandate is a sub-mandate, it is a component of the advanced and total mandates. If the advanced mandate were not lowered along with the waived cellulosic mandate, then there would be no change in the advanced biofuel requirement even though the contribution of cellulosic biofuel would fall. More other advanced biofuels would be required to offset the reduction in cellulosic biofuel. Although this option has been used when waiving the cellulosic biofuel mandate so far, we do not assume that this option is used in the future.

[4] See model documentation for more information about the representation of state RPS and federal and state support.

[5] Database of State Incentives for Renewables & Efficiency (DSIRE) provides detailed data about state RPSs (EERE and NCSU, 2011). These are aggregated in several steps that are outlined in the documentation, but summarized as follows. First, state-level electricity sales data are extrapolated to generate a base levels to which RPSs will apply in the future. Second, state RPSs are applied based on the share of load covered and, for states that apply the RPS to only investor-owned firms, the national share of sales from investor-owned utilities. Third, to reflect the variation in treatment of different energy sources using tiers (that carve out or set aside a portion of an RPS for a specific type of energy) and credit multipliers (that count some forms of energy more than others), as well as outright exclusions that disallow some energy types, the average of all credit multipliers is taken. In this average, if an energy source does not count at all towards the state RPS, then it has a value of zero. By taking each energy source times its average multiplier in the model, the variations in treatment of different energy sources is crudely represented. Fourth, the state RPS data are summed using extrapolated electricity sales and national electricity sales, and the share of each state covered (calculated from absolute targets, where necessary). In all cases, state RPSs are assumed to remain constant in percent terms at the final target level after the target year. The aggregated state RPS is expressed as a percent of total US use. It is 6.0% in 2011, 8.5% in 2015, 11.6% in 2020, and 12.2% in 2022.

[6] We use the US Treasury estimates for renewable energies tax expenditures to corporations available in the Pew Tax Expenditure Database (http://subsidyscope.org/tax_expenditures/db/group/1/?estimate=3). We treat separately the US Treasury Grant that we assume to cover 30% of the initial cost of a project, but we assume this program ends at the start of 2013.

[7] The question of when an RPS is high enough that it becomes binding – when electricity generation practices must change in order to achieve the minimum – is an important source of uncertainty. The EIA Annual Energy Outlook 2011 projects the share of renewable electricity in total electricity generation rising from 11% in 2011 to 14% in 2020. As we initially calibrate much of our outlook data to the EIA Annual Energy Outlook 2011, it is unsurprising that the share of renewables in total use in data presented here are similar. Consequently, the RPS is often non-binding in the early years of our experiments.

[8] Municipal waste is assumed to be readily and cheaply available, but only up to a limited quantity. An electricity firm would not have to pay much to collect waste that usually incurs fees for hauling and disposal. It is possible that an electricity firm would be paid to take municipal waste. However, our literature review suggests that there is only a limited volume of municipal waste that can be made available for electricity production after taking into account appropriateness of waste and the need for at least a certain volume to achieve an efficient scale in processing and using the waste. Here, we assume

that the price of marketable municipal waste that is appropriate for electricity use is bid up to the willingness-to-pay price – the price that electricity producers are willing to pay for municipal waste – even though the municipalities would likely be willing to part with their waste for considerably less than this amount if there continued to be no market for it.

[9] These are analogous to Renewable Identification Numbers used for biofuel mandate compliance.

[10] This is based in part on the understanding that almost all biomass used for electricity generation now comes from forest matter. Given this starting point, electricity from forest matter remains high throughout the baseline in most simulations.

[11] Here and throughout this report, we assume that a one ton increase of a type of biomass for one use causes a decreases the amount available for the other use by 0.4 ton, before considering price effects. This reallocation occurs only above a certain small threshold volume of production.

[12] We assume the other mandates are reduced by an equal amount, so there are is no offsetting increase in other biofuel requirements, such as for other advanced biofuels. (See endnote 3.)

[13] We do not estimate the potential that greater forest matter for bioenergy of the magnitudes shown here could reduce area available for traditional crops or raising livestock.

[14] The effect on the volatility of consumer electricity prices also depends on the correlation between shocks of renewable and non-renewable energy sources.

[15] As noted earlier, we assume no direct link between dedicated biomass crops and CRP area. The competition is indirect, as both compete, to some degree, for land historically devoted to traditional crops.

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