Energy system modelling

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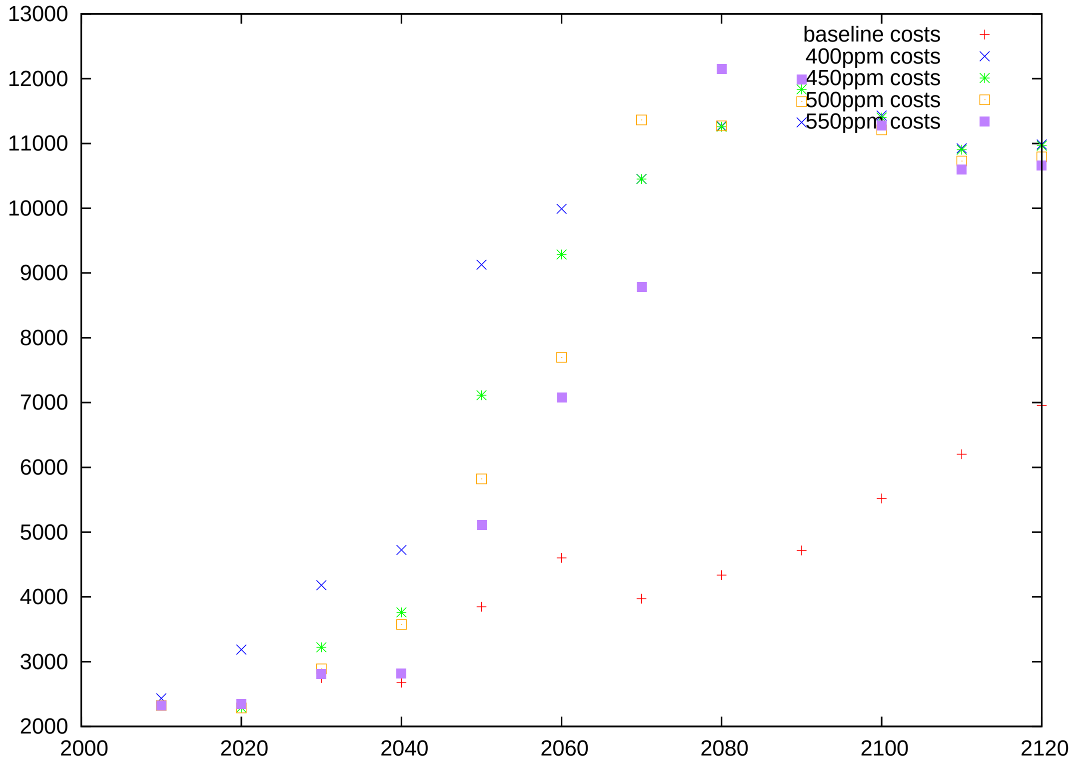
Note: The data file used was `resurs-data-2010-100331.dat`, without the corrections.

1 Question 1

The baseline cost, when there is no climate policy in place, is roughly 70 000 GUSD. From Figure 1 it's easy to see that the costs when imposing a cap on emissions will soar well above this value, and the yearly costs spike dramatically around the year 2030. The total costs increase steadily and already with a 550ppm cap they reach 82 000 GUSD. At 500ppm they reach 86 000 GUSD, at 450ppm 90 000 GUSD and at 400ppm they reach 106 000 GUSD, nearly 50% more than the cost of the baseline scenario.

The abatement costs can thus be calculated to be 12 000, 17 000, 21 000 and 37 000 GUSD, respectively.

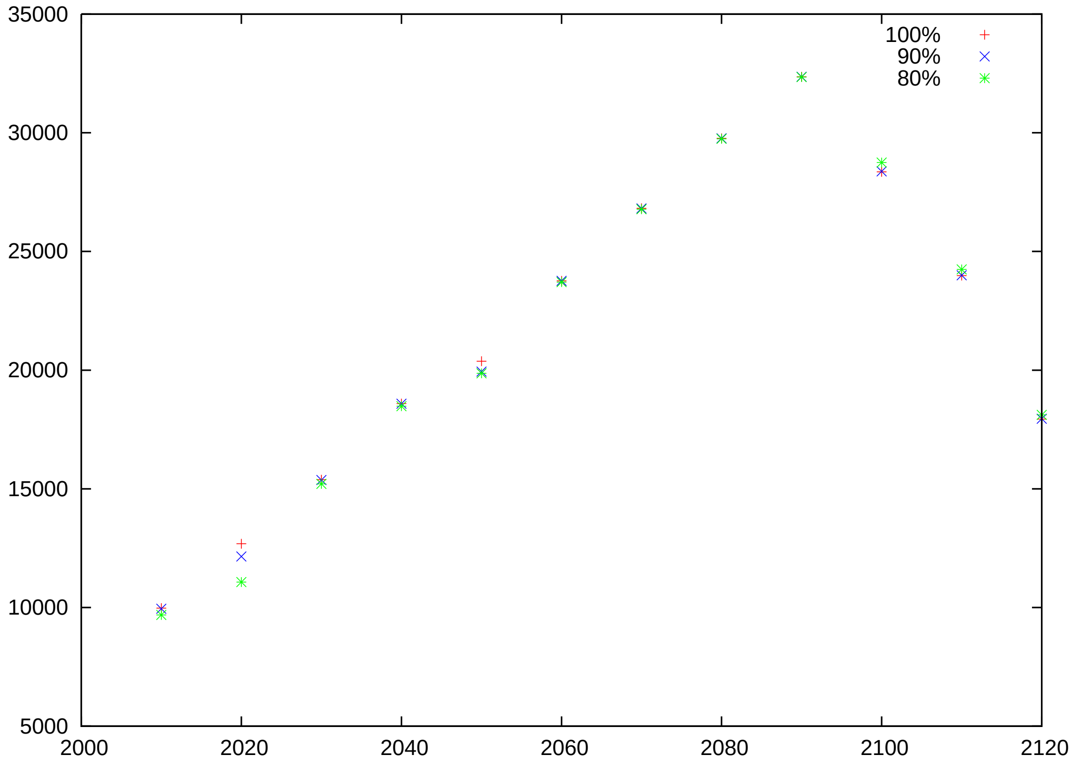


Figur 1: Yearly costs for different emission caps

2 Question 2

Since coal is a fairly abundant (but highly pollutive) energy source, use of coal will be a better choice than oil regardless of carbon emission caps. As seen in Figure 2a, coal usage will increase and peak during the first half of the century while (according to Figure 2b) oil usage will steadily decrease during the same time period. This is due to the fact that oil reserves are very low and thus we have to use other cheap energy sources (such as coal) to meet the global energy demand. As we progress and are willing to invest more in new, clean energy (the model reflects this), we can begin to replace coal with cleaner alternatives (this happens around 2030 in the capped scenarios).

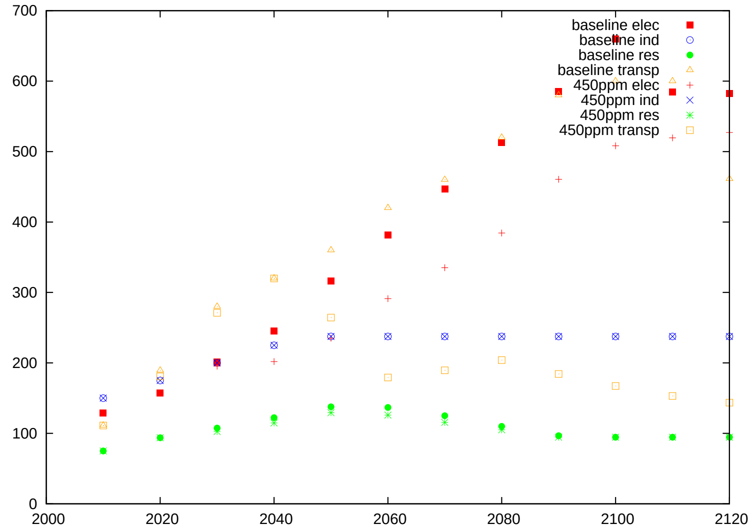
Reduced oil reserves result in an infeasible problem already at a reduction to 80%, and reducing the oil reserves by this small amount does very little to the carbon emission rates. Since the problem becomes infeasible at such low reductions of the oil reserves, it is imperative that oil usage is drastically lowered if the climate issue is to be solved at all.



Figur 3: Carbon emissions with alternative oil reserves (80% and 60% of the original amount)

3 Question 3

As shown in Figure 4, carbon dioxide abatement occurs mostly in the traffic sector. This could possibly be due to the fact that transport energy demand is both very high (and increases fast), and thus is a sector where one *should* invest a lot since reduction of emissions in this sector will have a large impact on the global emissions.

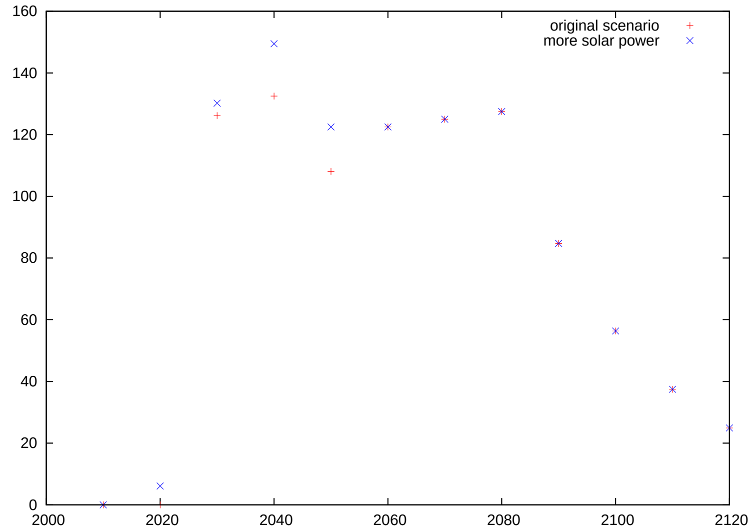


Figur 4: Carbon dioxide emissions by sector, both from the baseline and the 450ppm scenario

4 Question 4

As seen in Figure 5, the usage of biomass in the transport sector is only affected in the first half of the century. Since more solar power is used for residential heating (due to the increased fraction of usage), less of it will be used for transport. This means another energy source will have to replace solar power, and since biomass now is crippled in the industrial heat sector (and limited to 20% of its demand), this is the energy source that will repalce solar power in the transport sector.

After 2050 however, the usage of biomass in the transport sector is unaffected by these variable changes. This is likely due to the fact that biomass usage now has reached its cap, and that oil reserves are depleted and thus oil is not a viable energy source for transport.



Figur 5: Biomass usage in the transport sector, before and after the variable changes

5 Question 5

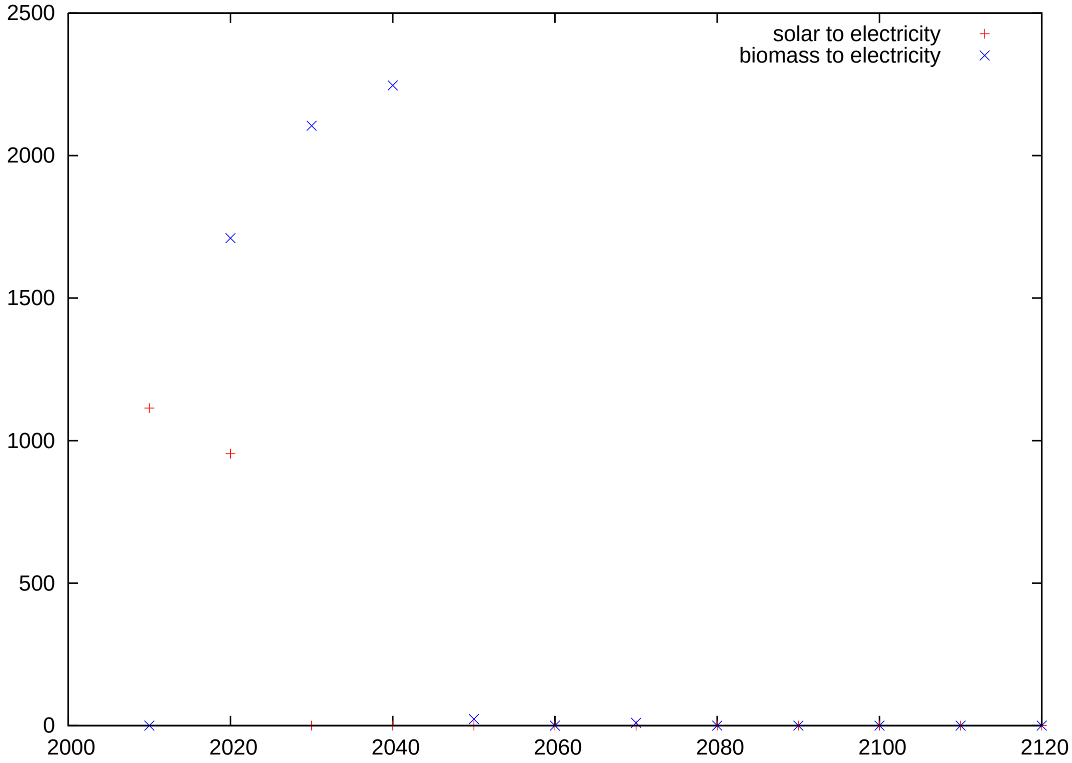
The general trend when increasing biomass supply is that electricity to a larger extent is supplied by biomass and a lesser extent by solar energy, while the other sources are unchanged. In the transport sector, solar energy is replaced by biomass at first, but in the later half of the century biomass is replaced by electricity in this sector.

A reduction of biomass potential of 10 EJ gives an increase in total cost of rougly 300 GUSD. This gives us a “penalty” of 0,25 GUSD per EJ and year when reducing the biomass potential. Biomass clearly is a vital energy source when it comes to reducing the overall cost.

However, this only holds for a reduction of around 40%, after which the penalty cost behaves in an increasingly nonlinear way and at a reduction of over 50% a reduction of 1 EJ costs almost 1 GUSD per year. Further reductions can be made, but at a reduction of over 80% the model becomes infeasible and no solution exists. This further indicated that biomass is an important part of the solution.

6 Question 6

The reduced cost of investing in equipment, seen in Figure 6, shows how much one has to cut down on costs in other sectors in order to be able to invest in this technology at a given time step. Hence, it implies that solar power isn’t really feasible until 2030, and that biomass won’t be feasible during the time period from 2020 to 2040.



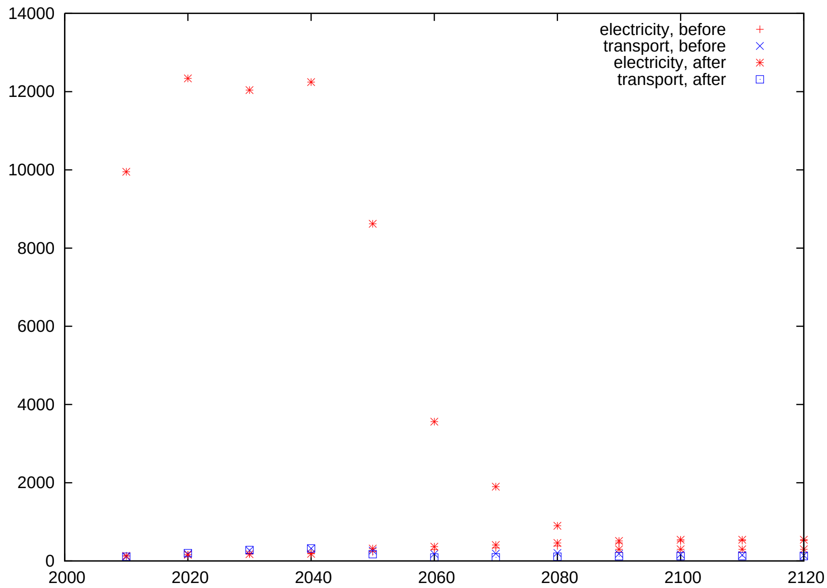
Figur 6: Reduced costs of investing in equipment for converting energy

7 Question 7

The impact by this change can be seen in Figure 7. The real effects don't occur until the last half of the century, and result in a larger part of transport being supplied by biomass and solar$_{H2}$ while electricity will be used to a lesser extent. This isn't surprising since biomass and solar$_{H2}$ is what the electricity sector mainly uses in the original scenario, and when a better energy source (such as nuclear power) is introduced in this sector, the other energy types are freely available to other sectors.

8 Question 8

The changes in energy supply are highly marginal, as seen in Figure 8, but basically consist of a decrease of energy used for electricity that is compensated by energy being used directly for transport.

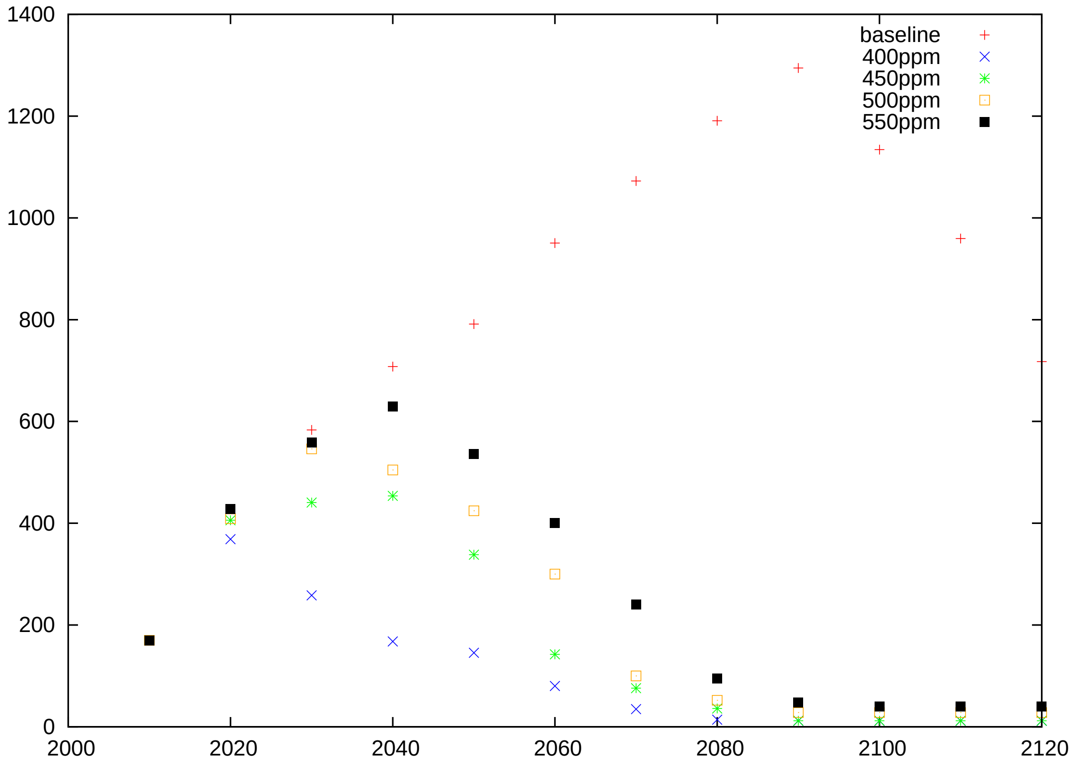


Figur 8: Energy usage before and after the change

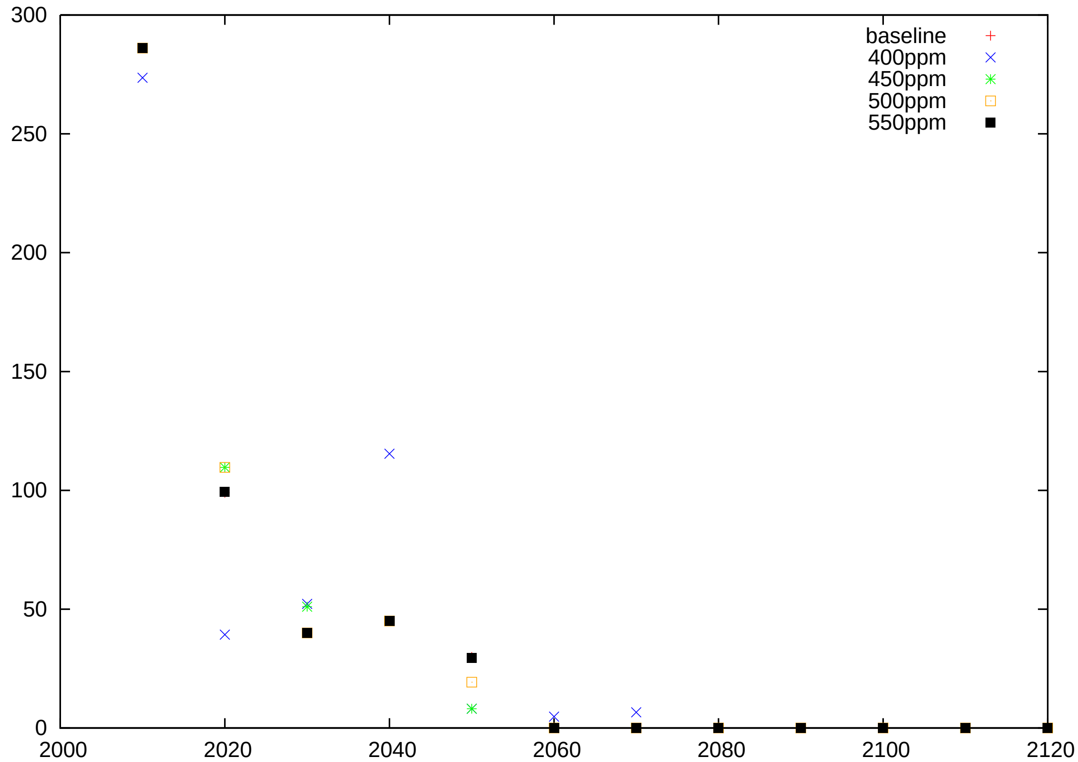
9 Question 9

This is not particularly difficult. All we really need to do is to add another energy input to the set of energy inputs, possibly a new fuel, and set the investment costs very high for this new energy type. If we also want to limit its use before a certain date (we expect the given energy type to be unavailable until a certain year) we must also set the maximum allowed investment in equipment for converting from this new energy type to any other energy type to zero for all time steps preceeding the year we expect to invent said technology.

This is probably something you could do if you wanted to include fusion energy in the model. The model would — for obvious reasons — be much less accurate when such technologies are included, but the results of this modified model might be *very* interesting.

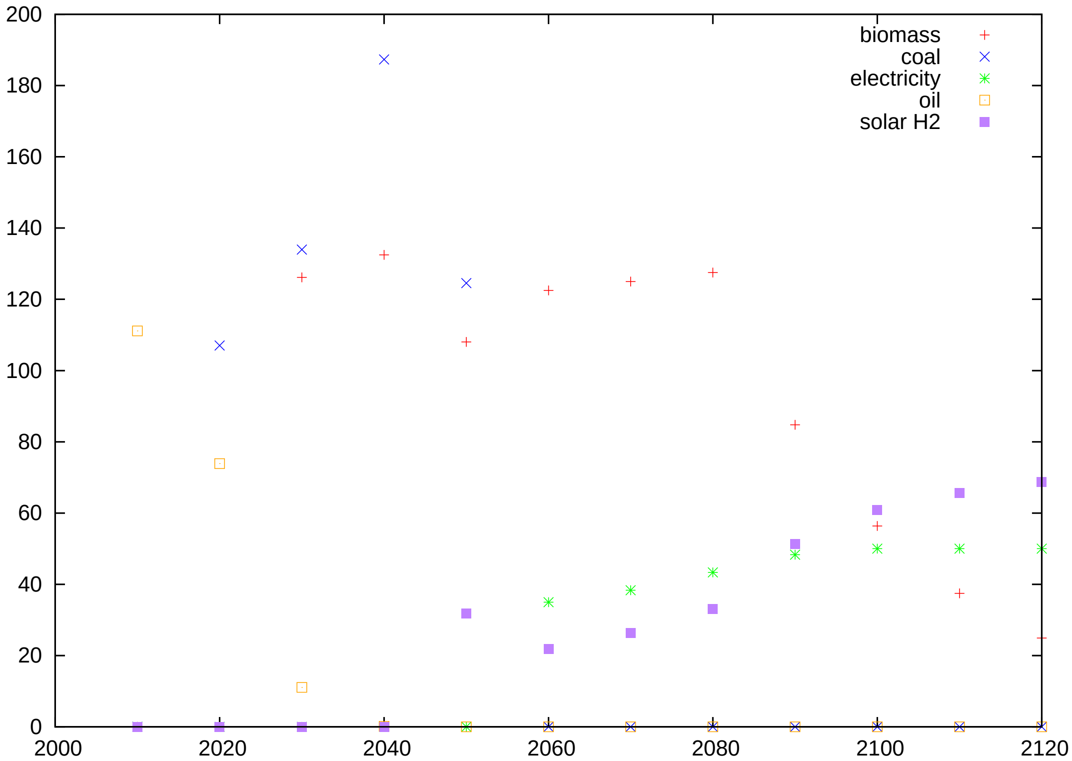


(a) Coal

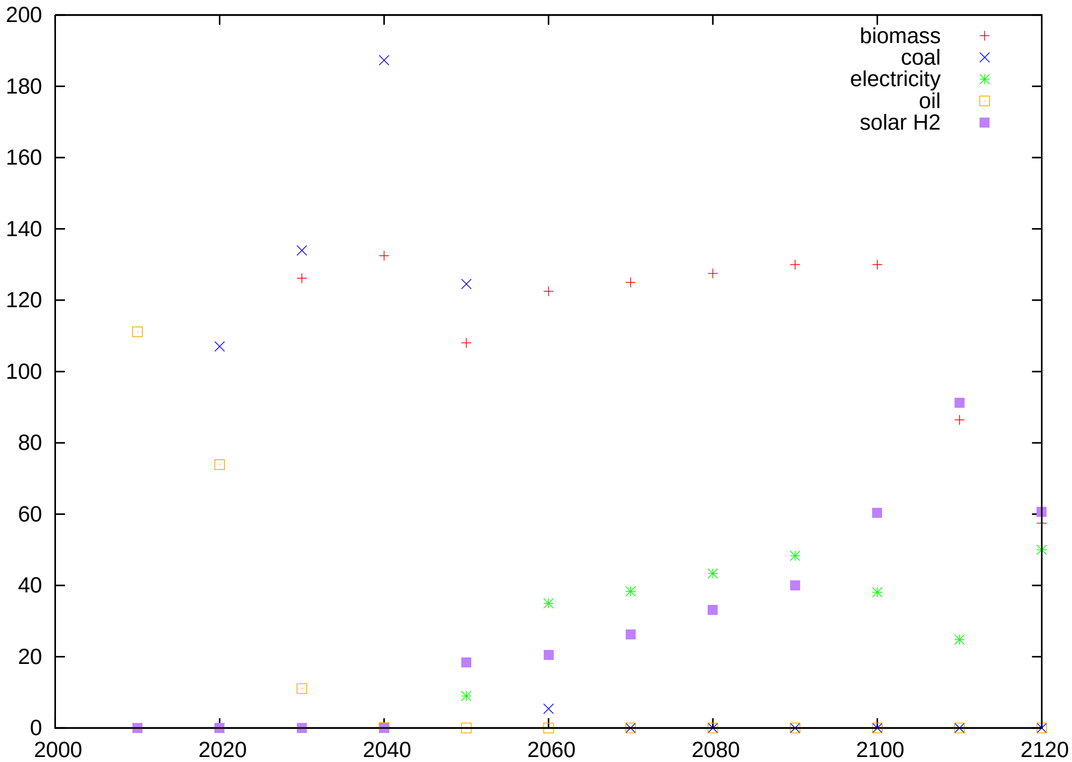


(b) Oil

Figur 2: Usage of coal and oil in the different scenarios



(a) Before the changes



(b) After the changes

Figur 7: Energy use in the transport sector