Simulations

(Version of March 14, 2011)

1 The Business-as-usual scenario

In this scenario the EU27 undertakes a GHG mitigation policy based on the unilateral EU27 20/20 climate action. In particular, the EU has committed itself to reducing its GHG emissions by 20% (compared to 1990 levels) and to increasing the share of RES in final energy demand to 20% by 2020. The GHG target is split to a 21% reduction in the ETS sectors and a virtual 10% reduction in the non-ETS sectors. The GEM-E3 model simulated this target by auctioning the GHG permits to the ETS sectors and by imposing a carbon tax to the non-ETS sectors. Permit trade is allowed only between actors involved in the ETS. The government revenues from permit auctioning are then recycled into the economy through a lump-sum transfer to households (support of households income due to energy cost increase). GHG emission reductions through CDM projects are not considered. In addition, the EU27 undertakes energy efficiency measures that lead to an average of around 8% efficiency improvements.

Table 1: M20 EU27 macroeconomic aggregates

	billion $ 2004				Annual % changes		% change from M0
	2005	2010	2015	2020	05-10	10-20	2020
Gross Domestic Product	11,441	11,753	13,111	14,579	0.54	2.18	-0.20
Investment	2,287	2,176	2,414	2,685	-0.99	2.13	-0.03
Public Consumption	2,655	2,893	3,222	3,548	1.73	2.06	0.00
Private Consumption	6,595	6,651	7,541	8,440	0.17	2.41	0.04
Exports	4,171	4,361	4,700	5,120	0.89	1.62	-0.54
Imports	4,268	4,327	4,766	5,213	0.28	1.88	0.07
Employment (in m. persons)	213	219	230	236	0.51	0.75	-0.16
Permit Price (€/ tCO_2)			7	19			

Source: own analysis based on GEM-E3 model.

2 Assumptions for the M30a scenario

The EU27 has committed itself to increasing its GHG mitigation effort to a 30% reduction (compared to 1990) if there is a comparable international GHG mitigation action. The GEM-E3 model has been used to evaluate the effects of the M30 policy in the environment of the business-as-usual equilibrium. The GHG emission reductions simulated in the M30a scenario follow the most recently announced pledges of both ANNEX I and non-ANNEX I countries. These are presented in Table 2 (the high pledges of ANNEX I are used in the scenario).

For each region participating in the GHG abatement effort all of its sectors are under a common target (-24% as compared to 2005 GHG emission levels) and participate to a single national/regional market. In this scenario full auctioning applies to all regions and sec-

Table 2: GHG emission reductions compared to 2005 based on the COP-15 pledges	
	2020
EU27	-24%
United States of America	-17%
Japan	-25%
Canada	-17%
Oceania (Australia and New Zealand)	-12%
Russian Federation	25%
Brazil	23%
China	54%
India	81%
Rest of Annex I	51%
Rest of the World	28%

Source: own analysis based on GEM-E3 model.

tors. Government auctioned revenues are recycled back to the economy through lump-sum transfers in households. The same efficiency measures undertaken by the EU27 in the M20 scenario are introduced. No other region of the world undertakes energy efficiency measures.

3 Assumptions for alternative 30% scenarios

Next, we have performed a series of simulations introducing step-by-step the features that define the new equilibrium labelled as green growth.

The M30b scenario is based on the same assumptions as the M30a case but it doubles the energy efficiency measures undertaken by the EU27.

To simulate the M30c scenario the GEM-E3 model was extended so as to include learning-by-doing. This scenario includes the assumptions of M30a and the learning-by-doing feature is activated. It should be noted that learning-by-doing is currently incorporated only to power producing technologies. Since the GEM-E3 model is recursive dynamic and its agents are myopic (in their optimization process they assume that current prices remain constant throughout their planning period), a quasi adaptive expectations approach is already introduced in the formulation of firms' investment plans. Within this approach investors' (firms') future expectations regarding their output are exogenously specified. In view of the additional investments required to achieve the GHG emission reductions and RES deployment implied by the M30a scenario, the exogenously specified growth rate of agents' future expectations was modified. In particular, the parameter defining the expected growth rate of all production sectors (apart from coal, oil and gas) is increased by an additional percentage point.

The M30d scenario combines the assumptions of the M30b and M30c scenario.

The green growth scenario maintains the assumptions of the M30d scenario and complements them with regime change on the labor market. In GEM-E3, this means that the parameter representing the insider-outsider divide on the labor market is lowered, as the lower unemployment that comes with green growth lowers the barrier between insiders and out-

siders. This is supported by the fact that the new jobs emerge mainly in the construction sector (including not only manual, but also clerical work), where on-the-job training delivers faster results than, say, in medical technology or financial services.

4 Results for M30a

The primary effects from imposing a GHG constraint into the model depend on two factors: i) the distance to the target (i.e. the amount of GHG emissions that is required to be reduced) and ii) the abatement options available to each region/country (i.e. substitutability between low and high GHG emitting technologies). The EU27 -30% GHG mitigation compared to 1990 levels is translated to a -11% in 2020 as compared to the same year of the reference case (which in our case is the M20 scenario). The secondary effects relate to the feedback of the rest of the economy to the changes occurring in the energy system. That is, changes in the relative prices of goods and services initiate a spiral of feedback effects among the different interconnected markets that ultimately lead to a restructuring of the overall economic system. The permit price that drives the GHG emission reduction is €50 t/CO_2e (€31 higher than the permit price in the M20 scenario). This equilibrium price incorporates both the primary and secondary effects of the policy intervention.

Adjustment to the emission constraint involves substitution away from commodities, the use of which (either in intermediate use or in final consumption) generates GHG emissions. This favours other production factors including labour, capital and mostly non-energy intermediate consumption. It also encourages consumption of non-energy goods and services, in the case of households. Since substitution cannot be perfect given the technical production possibilities and the preferences of the consumer, the agents would face higher overall costs. In particular, the permit price increases the user cost of energy driving firms and households to reduce their consumption of fuels and goods that are carbon intensive. Energy demand in firms and households is reduced by an average of 5% and 3.5% respectively at EU27 level in 2020 as compared to the reference case. The deployment of RES leads to a reduction of import demand for fossil fuels (3.7% at EU27 level in 2020 as compared to the reference case) freeing up resources to be used domestically for the production of the RES equipment. The substitution of imported energy by domestically produced energy services (e.g. RES) acts positively on domestic activity, but puts pressure on primary production factor resources. The full employment assumption of primary factors adopted by the GEM-E3 model implies that the additional demand for labour and capital will increase wages and the user cost of capital which will eventually increase the overall cost of production. Thus the combined effects are negative for activity and employment (see Table 3).

At firm level it is the energy sectors that play the most important role in the re-adjustment process. Coal production is substantially reduced due to the high increase in coal prices induced by the permit price. Oil demand is also affected especially in some EU member states where oil is used to a considerable extent for substitutable purposes (power generation and industry). Electricity use, to the extent that it is produced from coal and gas, also experiences

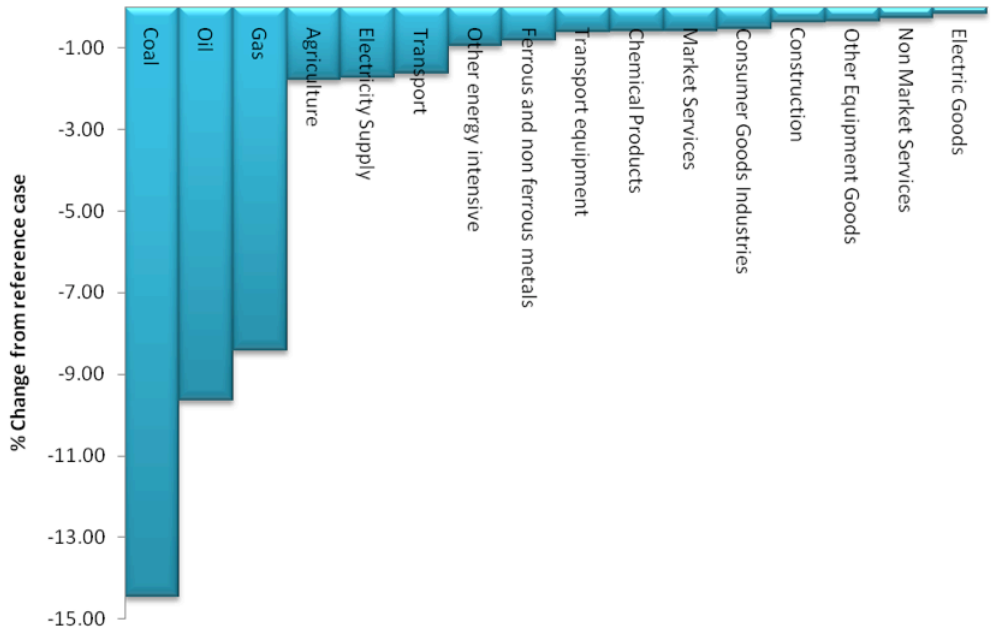
Table 3: Overview of M30 base case impact on key variables (EU27 % Changes from reference case)

	2020
GDP	−0.60
Energy Consumption	−5.35
Imports of fuels	−3.71
Employment	−0.33
Real wage	0.97
Equivalent Variation (in b. €)	−19.94

Source: own analysis based on GEM-E3 model.

substantial price increases and subsequent reductions in demand. Natural gas on the other hand being a substitute of other fossil fuels is affected less, implying an increase in its share as an energy source.

Figure 1: Changes at sectoral level (2020 – EU27)



Source: own analysis based on GEM-E3 model.

The negative impact on agricultural production mainly relates to the fact that agricultural activity is penalized both for its CO_2 and CH_4 emissions. Apart from the energy sectors and agriculture, it is the transport and energy intensive sectors that contribute most to the economic adjustment. The sharp reductions in the metals and the chemical industry are attributed

both to the strong dependence of the metal industry on solid fuels and to the additional costs imposed to the chemical industry as a result of its HFC and N_2O emissions. Transport also presents a reduction in its production as compared to the reference case due to its heavy dependence on solid fuels. Production of transport equipment is linked to the activity of the transport sector hence producing a similar decrease, albeit to a lower extent, in its production compared to the reference case.

Equipment goods, construction and electrical goods show virtually zero change from the reference case. This is attributed to the importance of these sectors in manufacturing both the RES equipment and the equipment required for the non energy related GHG abatement technologies.

5 Results for alternative 30% pathways

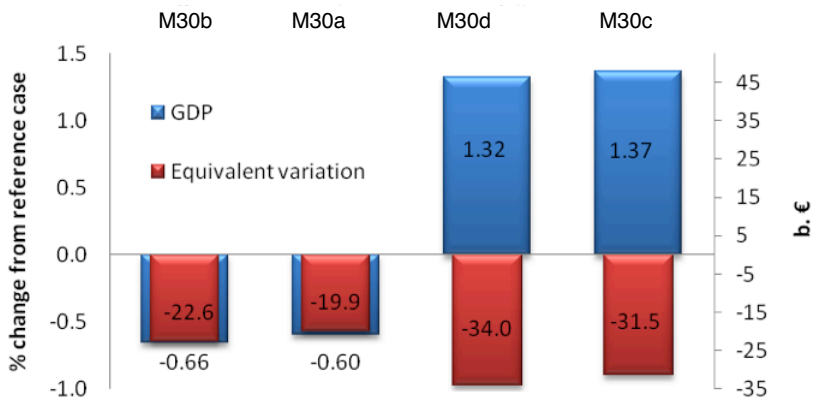
This section provides modifications of the M30a scenario that introduce stepwise the features defining the new growth path simulated in the green growth scenario. They relate to additional energy efficiency improvements (M30b), learning-by-doing and adjustment of investment expectations (M30c); with M30d including all characteristics of the above.

The energy saving programme (assumed in the M30b scenario) implies a demand side effect and an efficiency effect for the economy. The energy efficiency effect leads to a permanent improvement of energy productivity in its use in the production process and in its use in household consumption whereas the demand effects lead to an increase in the demand for goods required to construct the energy saving equipment during the policy implementation period. The effects from building the energy saving equipment are decomposed in a demand push effect for the whole economy and an increase in production costs. The demand-push effect increases domestic activity, employment and imports while the increase in production costs entails a loss of competitiveness for the economy. These effects are not permanent in the sense that after the period of intensive implementation of the policy the demand-push effects slow down, hence exerting a downward pressure on labour demand and ultimately on wage rates. On the other hand the effects from energy efficiency improvement are permanent leading to lower emissions and lower levels of energy consumption. So in the long run both, firms and households, will be able to free-up resources that were previously used for the consumption of energy products that are re-allocated to new investments (through increased savings) or to additional expenditure in other consumption categories. Consequently, the effect of the energy saving programme on GDP is negative (see Figure 2) in the short term (i.e. in 2020, as examined here) but could be positive in the long-term (i.e. once the energy saving expenditure stops and only the permanent energy efficiency gains are realized).

The M30c case implies additional investment as compared to the reference case and hence increased overall activity (see Figure 2). In this case GHG emissions increase and hence the price signal should be higher in order to achieve the GHG emission reduction target.

In the M30c scenario, households' savings increase in order to finance the increased demand for investments triggered by the higher expected growth rate. Increased savings of

Figure 2: GDP and Equivalent variation in M30 simulations



Source: own analysis based on GEM-E3 model.

households act to the detriment of consumption and hence this scenario presents one of the highest welfare reductions (as these are measured through the equivalent variation which is a money metric utility measure). In the M30c scenario, the EU27 economy is found to be more competitive with respect to the other scenarios examined. This is attributed to two factors: i) the additional investment expenditures increase the capital stock of the economy and hence relieve the upward pressure in the user cost of capital and ii) the learning-by-doing effect reduces, relative to the other scenarios examined, the unit production cost of electricity.

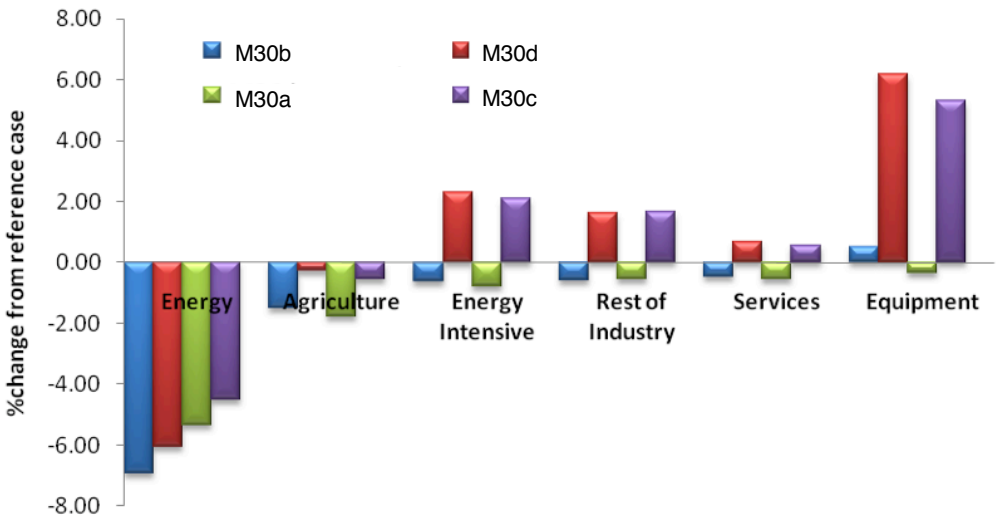
From a sectoral point of view energy savings, by reducing unit demand for energy, also reduce the expenditure of the firm allocated to energy, but increase the expenditure in non energy commodities that are needed to implement the energy saving technology. This implies an increased demand for services and goods that are used for the construction of the energy saving equipment. Since part of this equipment is produced within the EU, sectors like electrical goods, other equipment goods and services of credit and insurance increase their output and employment (Figure 3). This effect is more pronounced in the M30d full case that implies increased activity not only to the firms producing the energy saving technology but also to firms that produce the RES equipment.

6 The green growth scenario

For this scenario, we combine the assumptions of M30d with a regime change on the labor market: the elasticity of the short-run Phillips curve that in GEM-E3 represents the strength of the insider-outsider division on the labor market is modified so as to reflect the weakening of this division in a situation of high productivity growth and low unemployment.

This scenario suggests that post-crisis Europe can revitalize its economy by developing a credible vision of additional investment leading to higher growth and more jobs. The chal-

Figure 3: Production in M30



Source: own analysis based on GEM-E3 model.

lenge of building a low-carbon economy can provide that vision. In line with OECD terminology (see www.oecd.org/greengrowth) we label the result as *green growth.* What will make the difference against business as usual is not simply investment in windfarms and the like. It is the shared understanding that developing the quality of life that comes with a sustainable future provides plenty of avenues for mutually reinforcing investments – in education, health, entertainment, housing, transport, and much more. In this perspective, raising the European climate target from 20% to 30% emission reduction can open the way towards higher growth and increased employment.

The financial crisis has reduced emissions, but in the wrong way. Now the target of reducing greenhouse gas emissions by 20% in 2020 as compared to 1990 is not a challenge any more. It has become too weak to mobilize innovations and to stabilize political will. Sticking to that target is the equivalent of digging deeper while being stuck in a hole.

Clear policies, however, associated with a decisive move to a 30% target, can lead Europe towards a new growth path, one that is doubly beneficial for the climate and the EU economy. For this purpose, the climate target must not be pursued in isolation, but be embedded in a comprehensive range of measures, setting expectations for growth of the European economy at a more ambitious level. What matters is to explicitly declare an ambitious growth target in the aftermath of the financial crisis and to pursue this target on a variety of fronts – including incentives for additional investment, growth-oriented fiscal policy, public procurement, and of course climate policy.

The question is whether in the coming decade Europe will accept the challenge of increasing economic growth while reducing both unemployment and greenhouse gas emissions. New model results show that these three goals can actually reinforce one another. The simulations

performed for the present study assume domestic reductions of 30% and no international climate agreement that would go beyond the modest pledges made in the Copenhagen Agreement of 2009. If more ambitious goals should be pursued in the future by major economies, the positive impacts for Europe would be larger. Under the given assumptions, over the coming decade raising the EU's climate target from 20% to 30% can foster the following outcomes (Table 4):

- increase the growth rate of the European economy by up 0.6% per year
- create up to 6 million additional jobs Europe-wide
- boost European investments from 18% to up to 22% of GDP in 2020
- increase European GDP in 2020 by $\$_{2004}$842 bn

Table 4: Macroeconomic features, EU27

	Green Growth	Business as Usual	Δ
GDP in 2020 (billion $\$_{2004}$)	15421	14579	5.77%
GDP growth-rate 2010–2020	2.8%	2.2%	0.6*pp*
Unemployment rate in 2020	5.3%	7.6%	−2.3*pp*
Number of unemployed (millions)	13.4	19.4	−30.9%
Investment in 2020 (share of GDP)	22.4%	18.4%	4.0*pp*
Investment in 2020 (billion $\$_{2004}$)	3457	2685	28.8%
Emissions (Mt of CO_2e)	3927	4414	−11.0%
Carbon Price (€/t CO_2)	32.19	19.47	65.3%

Δ: Difference 20% vs. 30% either as percentage of 20% value or as difference in percentage points (pp).; Source: own analysis based on GEM-E3 simulations.

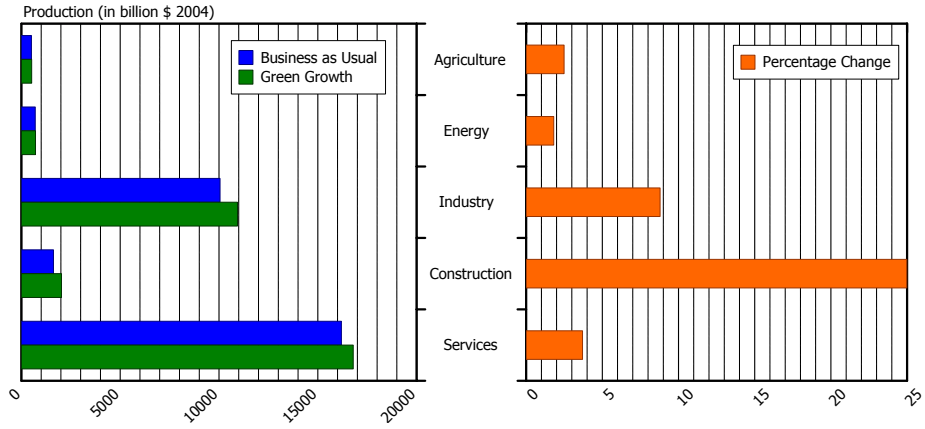
There are two reasons why this may seem too good to be true. First, it is often taken for granted that GDP can only be increased with increased emissions. There are, no doubt, situations where this is true, but in Europe in the years to come serious emission reductions imply higher growth than business as usual. The reason is straightforward: such reductions require a renewal of the built environment, and the built environment is by far the largest component of the overall capital stock. Therefore, its renewal implies larger investment and therefore larger growth. To a lesser, but still significant extent, the same is true for investments in the energy efficiency of machinery and in renewable energy.

The second issue of relevance here is whether larger investment can indeed generate higher growth beyond the 2.2% that business-as-usual promises. The fact that before the financial crisis many European countries did indeed experience much higher growth suggests that this may well be possible. And there is ample evidence to the effect that investment induces productivity gains via learning-by-doing, especially in the case of new technologies like renewables or new building materials.

6.1 Sectoral dynamics

Along the new growth path, all broad economic sectors – agriculture, energy, industry, construction, and services – increase production (Figure 4). Even the energy sector gains, mainly because of the expansion of renewables. The largest procentual – although not absolute – increase happens in construction. The new growth path implies a major effort to retrofit buildings and enhance the built environment. This is advantageous in view of employment because people with very different vocational skills can operate in this sectors after a few months of on-the-job training (in construction, as in the industry, nowadays the majority of jobs is not centered around manual work - and there too, on-the-job training can be very effective).

Figure 4: Production by Sector, EU27



Source: own analysis based on GEM-E3 simulations.

Emissions are reduced in all sectors except construction. The emissions reductions achieved by increased energy efficiency of buildings is much larger than the additional emissions from construction, however. Across the European economy, emissions are reduced by increasing energy efficiency and shifting from coal to renewables and gas. Energy efficiency is mainly, but not only, a matter of buildings. Over the next decade, renewables will be mainly wind, both on- and offshore. Carbon capture, photovoltaics and nuclear cannot make much of a difference over this time span. Nevertheless, they will be important to prepare for the longer term. The evolution of production costs and public acceptability will determine their future prospects.

The shift towards gas sometimes can raise concerns about energy security. European imports of natural gas, however, are reasonably diversified. The largest supplier, i.e. Russia, delivers just one third of total imports. Other major suppliers are Norway, Algeria, and Qatar. Due to the expansion of shale gas in the USA and the Chinese determination to limit dependency on energy imports, Europe is a vital customer for Russia. However, Eastern European

countries need improved transport opportunities for gas imported into Western Europe, and in order to deal with the vagaries of fossil fuel markets storage facilities need to be improved across Europe.

6.2 Regional dynamics

Not only is the new growth path quite balanced with regard to sectors, it is also remarkably balanced between old and new member states, i.e. EU15 and EU12 countries (Tables 5 and 6).

Table 5: Macroeconomic features, EU15

	Green Growth	Business as Usual	Δ
GDP in 2020 (billion $\$_{2004}$)	14373	13594	5.7%
GDP growth-rate 2010–2020	2.7%	2.1%	0.6*pp*
Unemployment rate in 2020	5.1%	7.4%	−2.3*pp*
Investment in 2020 (share of GDP)	22.1%	18.1%	4.0*pp*
Investment in 2020 (billion $\$_{2004}$)	3178	2459	29.2%
Emissions (Mt of CO_2e)	3164	3581	−11.6%

Δ: Difference 20% vs. 30% either as percentage of 20% value or as difference in percentage points (pp).; Source: own analysis based on GEM-E3 simulations.

Table 6: Macroeconomic features, EU12

	Green Growth	Business as Usual	Δ
GDP in 2020 (billion $\$_{2004}$)	1048	986	6.3%
GDP growth-rate 2010–2020	3.8%	3.2%	0.6*pp*
Unemployment rate in 2020	6.1%	8.7%	−2.6*pp*
Investment in 2020 (share of GDP)	26.7%	22.9%	3.8*pp*
Investment in 2020 (billion $\$_{2004}$)	279	226	23.5%
Emissions (Mt of CO_2e)	763	833	−8.4%

Δ: Difference 20% vs. 30% either as percentage of 20% value or as difference in percentage points (pp).; Source: own analysis based on GEM-E3 simulations.

In both groups of countries, average growth rates are about 0.5% larger on the new growth path than for business-as-usual. This also means that the catch-up process of EU12 is maintained. The unemployment rate, which is somewhat higher in the EU12, decreases slightly more in this group of countries. Emissions, which are much larger in EU15, decrease more there. Overall, it is clear that none of the two groups of countries is at a disadvantage with the new growth path.